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THE FELDSPARS OF THE NEW ENGLAND AND NORTH APPALACHIAN STATES

BY

A. S. WATTS

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CONTENTS.

	Page.
Introduction	3
Feldspar—Availability, grades, and uses	4
General conditions governing the mining of feldspar	6
Origin, character, and mode of occurrence of the feldspathic rocks	7
The feldspar districts of the New England and North Appalachian States	9
Maine	9
Boothlay district	9
Mount Apatite district	10
Mount Mica district	10
Other deposits	11
Analyses of Maine feldspars	11
New Hampshire	12
Massachusetts	12
Connecticut	12
New York	13
Ticonderoga district	13
Batchellerville district	14
Analyses of feldspars from Batchellerville district	15
Westchester County district	15
Properties of feldspars from Westchester County district	16
Pennsylvania	16
Maryland	19
Virginia	20
North Carolina	21
Georgia	22
Quality of the product	22
The color of feldspars	23
Description of specimens shown in Plates II and III	24
Minerals associated with feldspar in pegmatite	25
Quartz	25
Muscovite	25
Biotite	26
Garnet	26
Beryl	27
Tourmaline	27
Magnetite	28
General composition of the marketed product	28
Feldspar classification	28
Potash feldspars	29
Soda feldspars	30
Lime feldspar	30
Barium feldspar	30
Feldspar series	30

Feldspar classification—Continued. Page.
Effect of composition on properties of feldspar.......... 33
Deformation tests of potash feldspar-soda feldspar mixtures.......... 33
Results of tests.......... 34
Discussion of results.......... 35
Deformation tests of feldspar-quartz mixtures.......... 36
Experiments with potash feldspar-quartz mixtures.......... 36
Conclusions.......... 38
Deformation tests of soda feldspar-quartz mixtures.......... 38
Discussion of results of tests.......... 39
Deformation tests of commercial potash feldspar-quartz mixtures. 40
General conclusions on feldspar-quartz deformation tests.......... 41
Caution regarding interpretation of the above data.......... 42
Deformation tests of feldspar-beryl mixtures.......... 42
Deformation tests of feldspar-muscovite mixtures.......... 43
Deformation tests of feldspar-biotite mixtures.......... 44
Effect of kaolin on properties of commercial feldspar.......... 46
Deformation tests of feldspar-kaolin mixtures.......... 46
Kaolinization of feldspar and significance.......... 46
Method and procedure.......... 47
Data and results.......... 48
Conclusions.......... 49
Refiring.......... 49
Kaolin-feldspar-quartz tests.......... 50
Mixtures high in kaolin.......... 51
Graphic granites as a source of feldspar.......... 51
Properties of graphic granites.......... 53
Feldspar-quartz ratio in graphic granites.......... 53
Variation in granites throughout a given district.......... 54
Relation between pyrometric behavior and feldspar constituents.......... 55
Preparation of samples.......... 55
Results of tests.......... 56
Determination of quartz content.......... 57
Normative composition of graphic granites.......... 58
Prospecting and sampling.......... 60
Sampling a dike.......... 61
Testing feldspar.......... 63
Temperature of fusion.......... 63
Testing with standard cones.......... 64
Method of testing.......... 65
Use of pyrometers.......... 66
Thermoelectric pyrometer.......... 67
Heat-radiation pyrometer.......... 67
Optical pyrometer.......... 67
Properties of feldspar in porcelain mixtures.......... 68
Testing by means of standard trials.......... 68
Method of preparing trials.......... 68
Firing.......... 69
Vitrification range.......... 69
Color.......... 69
Translucency.......... 69
Shrinkage.......... 69
Test under glaze.......... 70
Blank or standard trial for feldspar.......... 71

Page.
Quarrying and quarrying methods.......... 71
The opening of a quarry.......... 72
Removing the overburden.......... 73
Quarrying the dike material.......... 74
Sorting the material.......... 75
Quarrying feldspar below water level.......... 75
Draining the quarry.......... 76
Methods of drainage.......... 76
Siphon.......... 76
Pumps.......... 77
Steam pump.......... 77
Cornish pump.......... 77
Compressed-air pumps.......... 77
Electrically driven pumps.......... 77
Cause of pump trouble, and remedy.......... 77
Haulage methods in quarries.......... 78
Locomotives.......... 78
Aerial tramways.......... 79
Preparation of the feldspar for market.......... 79
Crushing and pulverizing the feldspar.......... 79
Drying the crude feldspar.......... 80
Crushing the feldspar.......... 80
Rock crushers.......... 80
The buhrstone chaser.......... 81
Sieving the crushed feldspar.......... 83
Separating the mica from the feldspar.......... 83
Pulverizing the feldspar.......... 83
Ball mills.......... 84
Tube mills.......... 86
Conical mills.......... 87
Bolting.......... 87
Watering.......... 87
Effect of time on grinding of feldspars.......... 88
Tests to determine effect of time on degree of fineness.......... 89
Classification methods used.......... 89
Schultze elutriation apparatus.......... 89
Results of tests.......... 90
Discussion of results.......... 93
Handling the feldspar from quarry to consumer.......... 93
Chemical analyses of samples.......... 95
Feldspar quarries, mines, and prospects.......... 98
Maine.......... 100
Hancock County.......... 100
East Orland. Pegmatite dikes.......... 100
Properties in standard porcelain mixture.......... 100
Lincoln County.......... 100
New Castle. John Glidden property.......... 100
Properties in standard porcelain mixture.......... 101
Edgecomb. Abandoned quarry.......... 101
Properties in the standard porcelain mixture.......... 102
Edgecomb. Hull property.......... 102

Feldspar quarries, mines, and prospects—Continued.
Maine—Continued. Page.
Sagadahoc County........ 102
Georgetown. Noble and Smith prospects........ 102
Properties in standard porcelain mixture........ 102
Cathance. Alfred Graves quarry........ 102
Properties in standard porcelain mixture........ 103
Cathance. Maine feldspar quarry........ 103
Properties in standard porcelain mixture........ 103
Cathance. Maine graphic granite quarry........ 103
Properties in standard porcelain mixture........ 104
Cathance. Trenton quarry........ 104
Cathance. Old W. G. Willis quarry........ 104
Cathance. Old Golding quarry........ 105
Cathance. New W. G. Willis quarry........ 105
Properties in standard porcelain mixture........ 106
Cathance. Old Fisher quarry........ 106
Properties in standard porcelain mixture........ 107
Topsham. Maine Feldspar Co. deposit........ 107
Properties in standard porcelain mixture........ 107
Topsham. Mount Ararat quarries........ 107
Properties in standard porcelain mixture........ 108
Bath. Dauphin property........ 108
Topsham. Noyes property........ 108
Riggsville. Mason deposit........ 109
Properties in standard porcelain mixture........ 109
Riggsville. Noble deposit........ 109
Georgetown. Golding quarry........ 109
Properties in the standard porcelain mixture........ 110
Phippsburg. Joseph B. Perry property........ 110
Properties in standard porcelain mixture........ 111
Cumberland County........ 111
South Freeport. Staple Point deposit........ 111
Properties in the standard porcelain mixture........ 112
Auburn. Charles Sawyer deposit........ 112
Properties in standard porcelain mixture........ 112
Auburn. Dow property........ 112
Oxford County........ 113
Dixfield. Old Knox quarry........ 113
South Paris. Mount Mica deposits........ 113
Properties in standard porcelain mixture........ 114
Owls Head. Buckfield district........ 114
South Paris. Hooker Ridge........ 114
Properties in standard porcelain mixture........ 114
Hebron. No. 4 Hill quarry........ 115
Properties in the standard porcelain mixture........ 115
Hebron. Hibbs quarry........ 115
Properties in standard porcelain mixture........ 116
Paris Hill. Mount Rubellite deposit........ 116
Properties in standard porcelain mixture........ 116
Norway. Stevens Ledge........ 116

Feldspar quarries, mines, and prospects—Continued.
Maine—Continued. Page.
Androscoggin County 117
Auburn. Pegmatite dike 117
Properties in the standard porcelain mixture 118
Mount Apatite. Pulsopher deposit 118
Properties in standard porcelain mixture 118
Mount Apatite. Towne quarry 119
Properties in standard porcelain mixture 119
Auburn. Greenlaw quarry 119
Properties in standard porcelain mixture 120
Auburn. Maine quarries 120
Properties in standard porcelain mixture 121
Auburn. Pegmatite deposit 121
Properties in standard porcelain mixture 121
Auburn. Havey quarry 121
Properties in standard porcelain mixture 122
Auburn. Berry quarry 122
Massachusetts 122
Hampton County 122
Russell. Blandford quarry 122
Connecticut 123
Hartford County 123
South Glastonbury. Curtis quarry 123
South Glastonbury. Wiarda quarry 124
Properties in standard porcelain mixture 124
South Glastonbury. Old Wiarda quarry 124
Properties in standard porcelain mixture 125
South Glastonbury. Old Eureka quarries 125
Properties in standard porcelain mixture 125
South Glastonbury. Louis W. Howe quarry 125
Properties in standard porcelain mixture 126
Middlesex County 126
Rocky Hill. Andrews quarry 126
Properties in standard porcelain mixture 127
Portland. Eureka quarry 127
Properties in standard porcelain mixture 128
Middletown. Riverside quarries 128
Properties in standard porcelain mixture 129
Middletown. Consolidated quarry 129
Properties in standard porcelain mixture 130
Middletown. Bidwell quarry 130
Properties in standard porcelain mixture 130
Middle Haddam. Hallberg deposit 130
Properties in standard porcelain mixture 130
Middle Haddam. Middle Haddam quarry 131
Properties in standard porcelain mixture 131
Haddam. Haddam Neck quarry 131
Properties in standard porcelain mixture 131
New Haven County 132
Oxford. Bridgeport quarry 132

Feldspar quarries, mines, and prospects—Continued. Page.
New York 132
Essex County 132
Crown Point. Crown Point quarry 132
Properties in standard porcelain mixture 133
Ticonderoga. Barrett quarry 133
Properties in standard porcelain mixture 134
Ticonderoga. Ticonderoga quarry 135
Saratoga County 135
Corinth. Corinth quarry 135
Properties in standard porcelain mixture 135
Batchellerville. Batchellerville quarries 136
Main quarry 136
Properties in standard porcelain mixture 136
Second quarry 136
Properties in standard porcelain mixture 137
Third quarry 137
Properties in standard porcelain mixture 138
Hamilton County 138
Northville. Snell prospects 138
Properties in standard porcelain mixture 139
Fulton County 139
Northville. Rhodes quarry 139
Properties in standard porcelain mixture 139
Northville. Gifford prospect 139
Properties in standard porcelain mixture 140
Cranberry. Tyrol Mountain quarry 140
Properties in standard porcelain mixture 141
Westchester County 141
Bedford. Bedford quarry 141
Properties in standard porcelain mixture 142
Bedford. Kinkel quarry 142
Microcline pegmatite 142
Properties in standard porcelain mixture 142
Graphic granite 143
Albite pegmatite 143
Properties in standard porcelain mixture 143
Pure white albite 144
Properties in standard porcelain mixture 144
North Castle. Hobby quarry 144
Properties in standard porcelain mixture 144
North Castle. Bullock quarry 144
Properties in standard porcelain mixture 145
Pennsylvania 145
Delaware County 145
Darlington. Darlington quarry 145
Properties in standard porcelain mixture 146
Chester Heights. Chester Heights quarry 146
Properties in standard porcelain mixture 147
Chelsea. Bunting quarry 147
Boothwyn. Halsey quarry 147
Boothwyn. Boothwyn quarry 147
Properties in standard porcelain mixture 148
Elam. Brandywine Summit quarry 148
Properties in standard porcelain mixture 149

Feldspar quarries, mines, and prospects—Continued.
Pennsylvania—Continued. Page.
Chester County 149
Mendenhall. Old Walker quarry 149
Mendenhall. New Walker quarry 149
Properties in standard porcelain mixture 150
Embreeville. Embreeville quarry 150
Properties in standard porcelain mixture 151
New Garden. Lafferty quarry 151
Properties in standard porcelain mixture 152
Pomeroy. Meredith quarry 152
Properties in standard porcelain mixture 153
Chatham. Chatham quarry 153
Properties in standard porcelain mixture 153
Toughkenamon. Jenkins quarry 153
Properties in standard porcelain mixture 154
Toughkenamon. Carpenter quarry 154
Properties in standard porcelain mixture 154
Baker. Thompson quarry 154
Avondale. Hicks quarry 155
Properties in standard porcelain mixture 155
Baker station. Feldspar quarries 155
Properties in standard porcelain mixture 155
Avondale. Cooper quarries 156
Properties in standard porcelain mixture 156
Sylmar. Brandywine quarry 156
Properties in standard porcelain mixture 157
Sylmar. New Brandywine quarry 158
Sylmar. Old Brandywine quarry 158
Sylmar. Old Keystone quarry 158
Sylmar. Old Sparvetta quarry 158
Maryland 159
Cecil County 159
Conowingo. Rock Spring quarry 159
Conowingo. Bald Friar quarry 159
Properties in standard porcelain mixture 159
Baltimore County 159
Granite. Gifford quarry 160
Granite. Peach quarry 160
Properties in standard porcelain mixture 160
Davis. Dietz quarry 160
Properties in standard porcelain mixture 160
Ilchester. Ilchester quarry 161
Properties in standard porcelain mixture 161
Howard County 163
Marriottsville. Zepp quarry 161
Marriottsville. Warfield quarry 161
Properties in standard porcelain mixture 162
Marriottsville. Old Warfield quarry 162
Marriottsville. Baker quarry 162
Marriottsville. French quarry 163
Woodstock. Cavey quarry 163
Properties in standard porcelain mixture 164
Alberton. Alberton quarry 164
Properties in standard porcelain mixture 164

Feldspar quarries, mines, and prospects—Continued. Page.
Virginia 165
Bedford County 165
Lowry. McNichols quarry 165
Properties in standard porcelain mixture 165
Nelson County 166
Arrington. American rutile quarry 166
Prince Edward County 166
Prospect. Prospect quarry 166
Properties in standard porcelain mixture 167
Amelia County 167
Jetersville. Old Schlegel quarry 167
Properties in standard porcelain mixture 167
Amelia. Rutherford mica mine 167
Properties in standard porcelain mixture 168
Amelia. Pinchback mica mines 168
Amelia. Old Champion mica mine 168
Properties in standard porcelain mixture 169
Hanover County 169
Hewletts. Hewletts mica mine 169
Properties in standard porcelain mixture 169
Henry County 169
Ridgeway. Feldspar deposits 169
Properties in standard porcelain mixture 171
Ridgeway. Ridgeway Mica Co. mines 171
List of feldspar grinding mills 172
Publications on mineral technology 174
Index 177

ILLUSTRATIONS.

Page.

PLATE I. *A*, Weathered pegmatite dike at East Orland, Me.; *B*, Typical graphic granites, showing variation in size of crystals; *C*, Appearance of cones after deformation 10
II. Microcline and albite in natural colors 24
III. Andesine, microcline, and albite in natural colors 24
IV. Sketch map of part of Maine, showing feldspar deposits investigated 100
V. Sketch map of parts of Connecticut, New York, and Massachusetts, showing feldspar deposits investigated 122
VI. Sketch map of part of New York, showing feldspar deposits investigated 132
VII. Sketch map of parts of Pennsylvania and Maryland, showing feldspar deposits investigated 146
VIII. Sketch map of part of Virginia, showing feldspar deposits investigated 166

FIGURE 1. Deformation of potash feldspar-soda feldspar cones 35
2. Deformation of potash feldspar-quartz cones 37
3. Deformation of soda feldspar-quartz cones 39
4. Deformation of commercial feldspar-quartz cones 41
5. Deformation of feldspar-beryl cones 43
6. Deformation of feldspar-muscovite cones 44
7. Deformation of feldspar-biotite cones 45
8. Deformation of kaolin-feldspar cones 48
9. Diagram showing relation of rate of deformation to proportion of kaolin 49
10. Deformation of refined kaolin-feldspar cones 50
11. Deformation of kaolin-feldspar-quartz cones 50
12. Deformation curve of kaolin-feldspar series 52
13. Deformation of graphic granites and their feldspar components 56
14. Standard cone for deformation test 65
15. Jaw crusher 81
16. Buhrstone mill 82
17. Ball mill 85
18. Tube mill 86
19. Schultze elutriation apparatus 89
20. Results of classifying test of Maine feldspar 91
21. Results of classifying test of Connecticut feldspar 92
22. Deformation tests of feldspars of different fineness 94

THE FELDSPARS OF THE NEW ENGLAND AND NORTH APPALACHIAN STATES.

By A. S. Watts.

INTRODUCTION.

The Bureau of Mines has been conducting an investigation of the feldspar resources of the New England and North Appalachian States with a view to greater efficiency and economy in their utilization. Such an investigation was deemed necessary, not only because of the continued and increasing consumption of these minerals, but especially because of the demand for better technical control of the raw materials that are used by the white-ware industries of the United States. Most manufacturers of white pottery wares have only a limited knowledge of the origin, mode of occurrence, and methods of mining and preparation of the materials that they use.

Heretofore, owing to a belief that the supply of raw material was unlimited, the manufacturer had concerned himself chiefly with the solution of the problems of manufacture. Within the past few years, however, it has been found that difficulties arise in manufacture which can be traced beyond the manufacturing process and are believed to be due to a need of better control of the materials used.

Furthermore, as competition becomes more severe, more attention must be paid to selection of materials in order to minimize consumption and also to avoid unnecessary expense for transportation of material.

Doubtless the lack of interest as regards these details has arisen from the fact that in the past a considerable proportion of the white-ware ingredients has been imported and the manufacturer has been forced to rely on the samples submitted and the general uniformity of the source of supply to insure against variation of the material. An extra precaution arising from this lack of definite knowledge still prevails in the common practice of never depending on one source of supply for any one ingredient. Often the products of three or more producers are blended so that if any one shall vary without warning the variation arising from its use will not be sufficient to ruin the ware.

As the use of domestic materials has increased, the manufacturer has generally depended on the results of tests of samples submitted. The crude materials differ so greatly from the materials purchased, and the treatment necessary to prepare crude material for use involves such an intimate acquaintance with its peculiarities that the users had further cause to neglect to acquaint themselves with the details of its mining and preparation.

The investigations presented in this bulletin have been undertaken by the bureau with a view to a better understanding of the conditions which confront the producer of commercial feldspar and also with the object of determining wherein the various deposits of feldspar differ. This information will enable the manufacturer to choose the source of supply which is best suited to his needs, and in case a change is necessary to choose more intelligently the location from which to draw for his future supply.

FELDSPAR—AVAILABILITY, GRADES, AND USES.

Feldspars are by far the most abundant of all the minerals and are estimated to constitute nearly 60 per cent of the igneous rocks.[a]

However, of the feldspar having commercial value a large proportion is so intimately mixed with other minerals that recovery in the pure state would be very expensive if not impossible. The deposits yielding commercial feldspar are made up of a great variety of mineral combinations and occur in all grades as regards coarseness of crystallization. The deposits are widely distributed, and many of them are so far from railroads as to make mining impracticable.

At present there are at least 15 districts in the eastern part of the United States from which a commercial grade of feldspar is obtainable. Nevertheless, in the relatively short time that the supply of feldspar in the United States has been drawn on, the high-grade material has been almost totally exhausted in some districts and seriously depleted in several other districts. Conservation of these resources demands that cognizance of these facts be taken, and, if unnecessary wastefulness has occurred in the past, that steps be taken to correct the errors. It is vitally important that the material best suited be provided for the various industries and that a material available only in limited quantity shall not be employed in an industry which can use equally well a slightly inferior material which is available in greater quantity.

The chief users of feldspar are the manufacturers of white pottery ware. The manufacturers of glass and enameled metal wares are also extensive users of feldspars. The scouring-soap industry uses a limited amount, but careful selection as to color does not apply to the

[a] Clarke, F. W., Analyses of rocks from the laboratory of the United States Geological Survey: U. S. Geol. Survey Bull. 228, 1904, p. 20.

feldspar used in making soap. An enormous amount is annually consumed in the manufacture of roofing and for poultry grit, but these products do not require a material free from impurities and in most instances a low-grade feldspar is used. Pulverized feldspars of the potash varieties are also used as ingredients in some fertilizers and for this use the presence of iron-bearing impurities is not detrimental.

Although the above and many other uses have been found for feldspars of the different grades, it is a noteworthy fact that in few districts is a feldspar deposit being worked for more than one or at most two grades. If the deposit is opened for a pottery feldspar, the grades of feldspar not suited for this use are either not removed in the mining or if the nature of the deposit makes their removal a necessity they are thrown on the dump and there mixed with overburden and other refuse and their recovery at a later date would be more expensive than original mining. If the quarry is opened for a low-grade feldspar, the entire deposit suited for this use is mixed and sold for this purpose, no attempt being made to separate the high-grade feldspar that might be marketed for special purposes. The few attempts made in the past to select the feldspar into grades met with discouragement because the supply of choice feldspar was then so great that no special demand existed for pure feldspars. In recent years some of the older and more extensive deposits of pottery feldspar have become depleted of their choice feldspar and it has become a common practice to obtain pure feldspar in limited quantity from a new quarry and blend this with the output of the old one to make a marketable product, thus prolonging the life of the quarry as a producer of pottery feldspar.

The deposits from which the choice feldspar is obtained are left in the same condition as the quarries for the improvement of which the choice material is sought. The quarries thus robbed are in most instances small or handicapped by pooi transportation facilities. After the choice feldspar has been removed they are abandoned and often are filled with refuse so that reopening would not in most cases be practicable. If the necessary pure feldspar can be obtained from the quarries now opened and worked for low-grade feldspars, this system of incomplete mining can be largely dispensed with.

That the present demand for a pure feldspar in many of the industries is unwarranted is evidenced by practices both in England and throughout Continental Europe.

The enormous white-ware industries of Staffordshire, England, are dependent upon the coarse granites or pegmatites of Cornwall for their feldspathic material. This district does not produce any pure feldspar, but only material that is a mixture of feldspar and quartz with minor other minerals. The success which has attended the use of this material is indicated by the fact that enormous quantities of crude "Cornwall stone" are annually imported into the United States for manufacturers who find it more satisfactory for their purposes than any of the American feldspars.

In France the supply of feldspar is limited indeed, and the famous wares of Limoges are to-day made from semiweathered pegmatites of the St. Yrieix district. These are crushed and pulverized by wet grinding, and to them are added what additional kaolin and flint is necessary to produce the desired strength for molding and the demanded translucency when fired.

The feldspars of Scandinavia are also in reality pegmatites if one may judge from the analyses obtainable.

The foregoing indicates that deposits of pure feldspar no longer are available for the use of the European manufacturer, and he has found it possible to produce an equally satisfactory ware from a mixture of feldspar and such other minerals as are not actually injurious when the material is properly prepared.

Toward this same condition the American user of feldspar is rapidly approaching and conditions are not improved by ignorance of the gradual change that is occurring or by imagining that the same quality of material is being supplied as was obtained when the deposits were first opened.

As the necessity for substitution becomes apparent, the importance of a more thorough knowledge of the different feldspar producing districts of this country increases.

GENERAL CONDITIONS GOVERNING THE MINING OF FELDSPAR.

In mining feldspar the personal judgment of the operator and his numerous employees regulates the quality of crude material accepted and on the uniformity of this selection the manufacturer depends for the maintenance of the quality of his ware. Fortunately in most of the feldspar quarries the men employed have been trained by long acquaintance with the feldspars of the district, otherwise serious error in selection might easily result. The ordinary process of sorting the feldspar is as follows:

The quarried rock is piled in long rows and then a crew of men provided with light sledges sort the pieces, breaking off the impure parts. By this system, known as "cobbing," the rock is prepared for the mill.

The accepted material is then heaped in an open space, where it is exposed to the weather for a few weeks in order that the rains may carry away any dirt which may be adhering to the broken stone. The length of time allowed for the elements to effect the cleaning of the rock is dependent largely on the urgency of the demand for the crude material. All crude feldspar was formerly subjected to a thorough washing but this practice has been abandoned in recent years. Another cause of serious contamination is surface water containing iron salts which runs down the faces of the quarry and stains the rock. These stains or incrustations on drying adhere so firmly that any ordinary method of cleaning or washing fails to remove them.

ORIGIN, CHARACTER, AND MODE OF OCCURRENCE OF THE FELDSPATHIC ROCKS.

All the feldspar-bearing rocks are of igneous origin—that is, they have solidified from molten masses. The potash and soda feldspars, with which this work deals, are found chiefly in granites, which generally occur as vast intruded masses and consist essentially of quartz, feldspars, micas, and hornblende. Granite masses generally contain bodies of rock that is similar in composition to the granite itself but was intruded after the latter had more or less solidified. These intrusions are named according to the angle of their dip; those nearly vertical are called dikes and those more nearly horizontal are called sills.

These dikes or sills are generally pegmatite—that is, they are coarsely crystalline granite in which feldspar and quartz are the chief constituents; the other granite constituents may be totally absent or replaced by rare minerals. This pegmatite is the source of supply of the feldspar of commerce.

The character of the pegmatite dikes and sills varies widely. In some dikes the rock is of a comparatively uniform texture throughout and its contact with the granite walls which inclose it may be indistinct, indicating more or less blending of the two at the time of intrusion. Other dikes consist of a number of distinct and separate bands of rock of widely differing composition, indicating several distinct periods in the process of solidification.

When the crystallization is very coarse or the constituents of the dike are separated into distinct bands it is sometimes possible to obtain feldspar in commercial quantity absolutely free from associate minerals. In most dikes the feldspar and quartz are crystallized too intimately to permit of such a separation and the most that can be accomplished is the elimination of such associated minerals as are segregated or sufficiently coarsely crystalline.

The origin of pegmatite intrusions has been explained in various ways, but they are generally conceded to be of the same general mass as the original granite and to have been intruded into openings formed by eruptions of gases and vapors or by cracking of the crust of the granite mass on cooling. Often these crevices or ruptures extend beyond the granite mass and thus pegmatite dikes are often found extending through several different types of surface rock.

The shape of the dike is always lenticular, as would be expected of a mass intruded under greatly varying pressure into a mass of widely differing density. As the form of cooling cracks in a mass of solidifying granite would naturally vary in direction and width, the extent and directions of the pegmatite mass are very irregular, a zone of easily ruptured granite resulting in an expanded lens of pegmatite which may abruptly pinch out or be reduced to a mere stringer that at an uncertain distance expands again to a lens.

The structure of such a deposit is as variable as the dimensions. A pegmatite dike may abruptly change from a coarsely crystalline mass, practically free from any minerals except feldspar and quartz, to a finely crystalline mixture containing amounts of associate minerals which render it valueless as a source of commercial feldspar. Bodies of rock similar in composition to the wall rock are often found completely inclosed within the dike. These bodies or horses are most frequently found in the larger lenses and generally have sharply defined outlines, so that if reasonable care is exercised in mining no contamination of the feldspar need result from their presence.

This uncertainty in the continuity and uniformity of all pegmatite dikes must be taken into consideration in the development of any such deposit. Only by the most thorough preliminary prospecting and sampling can the operator be insured against failure through the sudden alteration or pinching out of the deposit.

A peculiarity of many dikes is the occurrence of remarkably clean pegmatite in considerable quantity in the upper part of the dike, whereas at a depth of 10 to 15 feet the different iron-bearing minerals begin, and the dike rapidly changes to a coarse biotite or hornblende granite and at greater depths to a fine-grained granite, which, however, is rarely of such quality as to be of any value. This form of structure has been the cause of much trouble where only surface samples have been taken before quarrying was begun. Surface areas of clean pegmatite underlaid by impure material are rarely of great extent and were it not for the fact that they often extend across the entire width of the dike could be easily detected and classified as lenses in the dike. Along the strike of the dike in both directions the dike material gradually changes to impure coarse granite, so that a proper survey would have warned the prospector of the uncertainty of the clean pegmatite continuing with depth.

The presence of a capping carrying a high content of biotite and garnets and so mixed with impurities as to condemn it as a possible source of feldspar has led many prospectors to ignore dikes which contain, below the surface, pegmatite of a quality equal or superior to much that is now being marketed. These cappings are sometimes only a few inches thick, but generally average 1 to 2 feet thick, and the removal of 1 or 2 additional feet of rock is often necessary before pegmatite of a marketable grade is reached.

The evidence of incomplete prospecting is everywhere apparent in the districts investigated by the bureau, and many valuable deposits have doubtless been overlooked by such practices.

THE FELDSPAR DISTRICTS OF THE NEW ENGLAND AND NORTH APPALACHIAN STATES.

MAINE.

In Maine there are at least three distinct districts where feldspar-bearing rocks exist in commercial quantity and several minor centers which are worthy of more thorough prospecting than the scope of this investigation has permitted. The most eastern point at which a commercial grade of feldspar is found in this State is at East Orland, Hancock County, where dikes of a medium-grade microcline pegmatite protrude in many places several feet above the surrounding country. The dikes are generally only a few feet thick and the exposed parts have weathered on their surfaces to a mass of sand (Pl. I, *A*), in which the quartz grains and the feldspar particles have been separated by the weathering, but below the surface the dikes seem solid and are comparatively free from the injurious impurities of most pegmatites. Inaccessibility is the only drawback to the working of these dikes.

BOOTHLAY DISTRICT.

One of the most important feldspar districts of the United States is the Boothlay district, which extends from Boothlay on the Atlantic coast to Mount Ararat, north of Brunswick, and embraces Sagadahoc County and the eastern part of Cumberland County. The feldspar of this district is a mixture of coarse microcline pegmatite and large masses of graphic granite. The dikes vary greatly as regards impurity. In the northern parts of the district the dike rock contains large lath-like crystals of biotite, the most common impurity in Maine feldspar, but in many deposits along the coast that mineral is largely replaced by black tourmaline. Albite in very limited quantity is finely intergrown with the pegmatite. The feldspar of this district is pale cream in color, the quartz in the pegmatites is clear or of the light shades of the smoky variety. Very little massive sugar quartz is found in this district. Beryl, mostly of the opaque variety which yields no gem material, is not uncommon in the dikes along the coast. The muscovite is ruled and yields little sheet mica.

MOUNT APATITE DISTRICT.

The Mount Apatite district extends west and southwest from Mount Apatite, Androscoggin County. The feldspar occurs almost entirely as isolated pegmatite lenses, which lack uniformity both as regards strike and dip. Albite pegmatite is associated with the microcline pegmatite in some deposits and is also found entirely separate. Lenses of practically pure milk-white albite are also present in a few dikes. These lenses are generally small and not capable of supplying any great part of the present demand for soda feldspar. One of the drawbacks to mining this soda feldspar is the fact that it is chiefly of the lamellar variety cleavelandite, which has a pronounced cleavage and breaks into small particles on handling, thus rendering it especially liable to contamination from surface material and associated impurities in the dike. The potash feldspar is a buff-colored microcline pegmatite of coarse crystallization, intergrown with small amounts of albite. Biotite is present in all the microcline pegmatite deposits and muscovite in sufficient quantity in a few deposits to justify its utilization for small punch mica.

The discovery of gem-bearing pockets in the pegmatite of this district has encouraged the working of many small dikes and much valuable feldspar has been obtained as a result. The chief gem mineral sought is tourmaline, which usually occurs inclosed in pockets of albite.

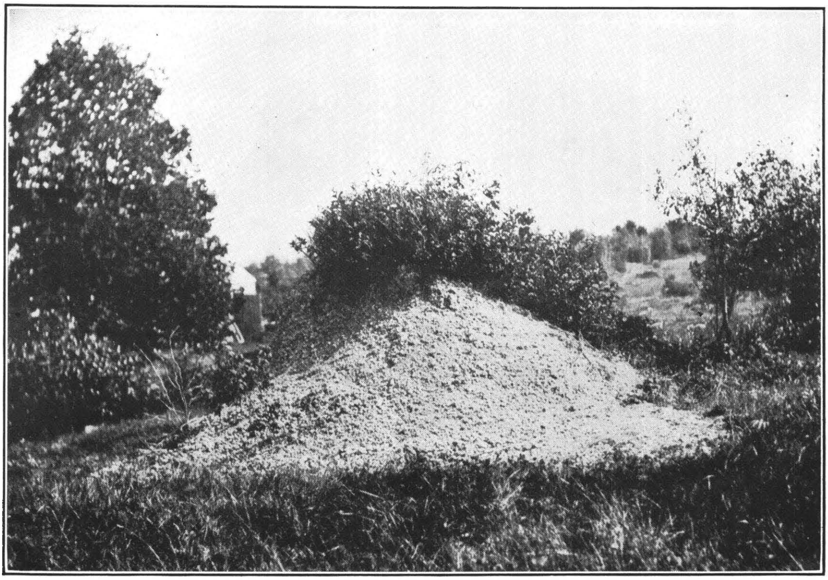
MOUNT MICA DISTRICT.

The Mount Mica district is situated in Oxford County with Mount Mica as a center. There are two distinct types of feldspar-bearing formations in this district: (*a*) Sharply defined microcline-pegmatite dikes standing almost vertical and having definite strike; and (*b*) irregular lenticular deposits of microcline pegmatite and albite containing pockets of gem minerals.

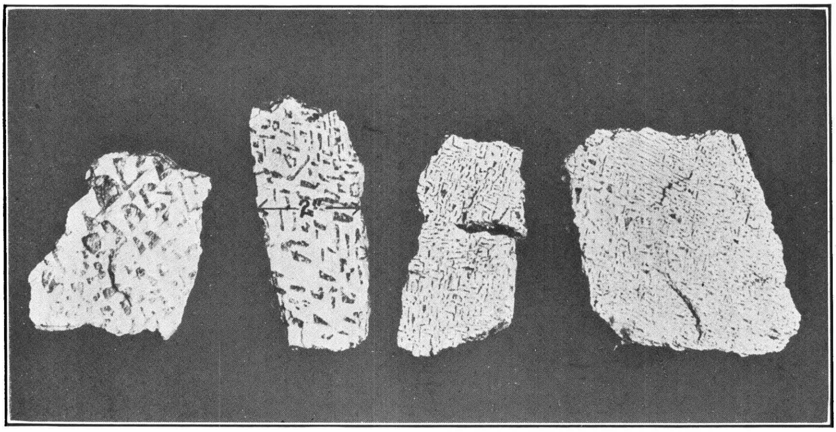
The sharply defined dikes are generally free from any detrimental impurities, except black tourmaline and biotite, and these are rarely associated in the same dike. Garnets are present in a few of these dikes, but rarely in sufficient quantity to seriously injure the product. Muscovite occurs in most of these dikes, and, as a rule, is confined to limited zones, which permits of its easy removal in mining, or is sufficiently coarsely crystalline to permit of its elimination by "cobbing."

The feldspar of these deposits is a pale buff to pale cream microcline. The associate quartz is chiefly of the smoky variety, being almost black in some deposits near Mount Rubellite, in the eastern part of this district. Massive sugar-quartz occurs in many of these dikes, and in the neighborhood of Paris is a fine grade of rose quartz.

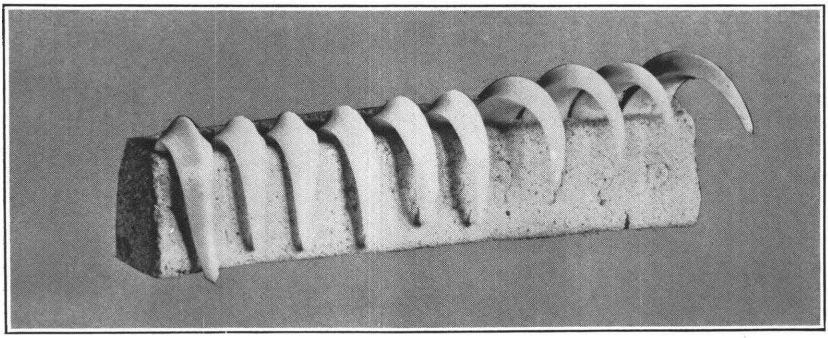
The irregular lenses of feldspathic rock which are distributed through this district can hardly be said to constitute a source of feldspar supply because the feldspar is so hopelessly mixed with other



A. WEATHERED PEGMATITE DIKE AT EAST ORLAND, ME.



B. TYPICAL GRAPHIC GRANITES, SHOWING VARIATION IN SIZE OF CRYSTALS.



C. APPEARANCE OF CONES AFTER DEFORMATION.

minerals that no miner would attempt to work the lenses for their feldspar alone. In the search for gems, which are found chiefly in this type of formation, much feldspar has been exposed and from time to time this has been removed and has added considerably to the feldspar production of the district. The feldspar of these deposits is a pale buff microcline and a milk-white albite.

OTHER DEPOSITS.

There are many small dikes of pegmatite in the State of Maine, which are not included in these districts, but they do not differ materially from the feldspars recorded. Throughout the State of Maine a remarkable uniformity prevails both in the potash and the soda feldspars.

ANALYSES OF MAINE FELDSPARS.

Samples of potash feldspar taken from various deposits, from south to north across the State, show the following analyses:

Analyses of potash feldspars of Maine.

[A. C. Fieldner, analyst.]

Constituent.	A	B	C	D	E
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
SiO_2	64.67	64.90	65.07	64.97	65.48
Al_2O_3	19.18	19.75	19.39	19.48	19.39
Fe_2O_3	.20	.12	.10	.04	.08
CaO	.99		Trace.		
MgO	Trace.	Trace.	Trace.	Trace.	Trace.
Na_2O	2.54	2.68	2.52	2.56	2.85
K_2O	12.76	12.04	12.58	11.76	11.51

These potash feldspars have a deformation range of 1,275° C. to about 1,295° C. (cone 7+ to cone 8+). They fuse to a transparent glass practically free from color.

The soda feldspars of the Mount Apatite district show the following compositions:

Analyses of soda feldspars from Mount Apatite district.

[A. C. Fieldner, analyst.]

Constituent.	Albite.	Albite pegmatite.
	Per cent.	*Per cent.*
SiO_2	66.36	71.55
Al_2O_3	21.35	18.11
Fe_2O_3	.12	.16
CaO	1.10	.46
MgO	.21	Trace.
Na_2O	9.74	8.72
K_2O	.73	.64

These soda feldspars have a deformation range of 1,270° C. to about 1,275° C. (cone 7 to cone 7+).

NEW HAMPSHIRE.

The pegmatite of New Hampshire has never been quarried for its feldspar content, but a quarry near North Groton, Groton County, has been opened for mica, and the feldspar of this deposit is similar to the Maine feldspar as regards physical properties and pyrometric behavior. No analysis is available.

MASSACHUSETTS.

An irregular dike of pegmatite containing many lenses of pure feldspar has been opened near Blandford, Hampden County, Mass. This deposit consists of a cream-colored feldspar, coarsely crystalline, associated with a clear or slightly smoky quartz. Optical and pyrometric tests indicate that it is a feldspar high in potash and low in soda. As no similar dikes are exposed in the vicinity of the quarry, and it had been abandoned on account of the expense of hauling to the railroad, which is 4 miles distant at Russell, Mass., this feldspar was not analyzed. A careful survey of this district would doubtless result in the discovery of other deposits of potash feldspar of equally high quality.

CONNECTICUT.

The feldspar-bearing pegmatites of Connecticut are situated along the banks of the Connecticut River in Hartford and Middlesex Counties, for a distance of about 20 miles. The center of this district is Middletown, and the feldspar deposits north of this point are confined to the east side of the river, whereas south of Middletown the deposits are found on both sides of the river.

The feldspars are constituents of coarse pegmatites which occur as well defined dikes of varying size and having a general northeast strike. The pegmatites of Connecticut are more free from associate minerals than those of Maine, but in structure and color the pegmatites of these two States are remarkably similar. Small lenses of albite or albite pegmatite are perhaps more common in Connecticut and the quartz content of the dikes is undoubtedly slightly higher than in Maine, but the method of handling the quarried product will control, to a great extent, the content of both these minerals in the marketed product. The amount and mode of occurrence of black tourmaline and biotite are about the same as in the Maine deposits, muscovite is perhaps slightly less prevalent but occurs in a finer state of subdivision. Garnets are rarely present and then only in negligible quantity; beryl is rarely found in quantity.

The general uniformity of the potash feldspars occurring in pegmatite in Connecticut is shown in the following analyses of samples taken from different parts of the district:

Analyses of Connecticut potash feldspars.

[A. C. Fieldner, analyst.]

Constituent.	A.	B.	C.
	Per cent.	*Per cent.*	*Per cent.*
SiO_2	64.65	65.24	66.02
Al_2O_3	19.10	19.74	18.99
Fe_2O_3	.14	.12	.08
CaO	Trace.	None.	None.
MgO	Trace.	None.	None.
Na_2O	2.32	3.04	3.12
K_2O	12.58	11.84	10.96

These feldspars have a deformation range of 1,275° C. to 1,290° C. (cone 7 + to cone 8). They are pale buff to pale cream and fuse to a practically colorless transparent glass.

Soda feldspar does not exist in commercial quantity in Connecticut, but a limited amount could be obtained by careful selection in handling the crude rock from the different quarries, as it generally occurs as small well-defined lenses in the pegmatite, and also as perthitic intergrowths in most of the microclines.

NEW YORK.

The feldspars of New York vary widely and do not in any respect resemble the feldspars of New England deposits.

The nature of the deposits, the mode of occurrence, and the general location divide the feldspar-bearing deposits of New York into three districts: The Ticonderoga, the Batchellerville, and the Westchester.

TICONDEROGA DISTRICT.

The Ticonderoga district includes the territory about Crown Point and Ticonderoga, Essex County. The feldspar of this district consists of a coarsely crystalline mixture of pearl gray microcline and sea-green plagioclase, the greater part being plagioclase, and contains much less quartz than the New England pegmatite. Biotite is the chief associated impurity and large quantities in the form of "books" are scattered throughout the entire deposit. It is extremely brittle and its removal by cobbing would be difficult. Calcite is intimately crystallized with the microcline in some deposits and its removal by cobbing would be almost impossible. The microcline has a highly developed cleavage and generally breaks into small cubelike fragments on the least blow, which adds to the difficulty of removing this material in an uncontaminated state. The plagioclase has no pronounced cleavage and breaks with more or less conchoidal fracture. It is opaque and has a vitreous luster. It contains from 0.50 to 0.60 per cent of iron oxide, although its color when fused would indicate a much higher iron content. It deforms at a temperature of 1,450° C. (cone 16) and would harden a potash-soda feldspar and hence, even if it were colorless, would be an injurious admixture. The microclines of this district are quite uniform in composition with the exception of the alkali content, which is slightly variable, as is apparent by the deformation temperatures of the feldspars.

The feldspathic dikes of the section are worked solely for material to be used in the manufacture of prepared roofing and for poultry grit. The presence of the impurities is therefore not of importance. Operators claim that attempts to sort the high-grade feldspar from the bulk of the dike material have not been profitable owing to the small proportion of feldspar of a sufficiently high grade to command a special price, and the greatly increased expense of handling. Small quantities of high-grade feldspar could, however, be obtained merely by selection when quarrying exposes a lense of pure or nearly pure microcline, and this selection should not greatly increase the expense of production, although it might necessitate a slight shift of quarrying operations while the high-grade material was being removed. The dikes of this district are very extensive both as to width and length, and it is to be regretted that the bulk of their contents is so low grade.

BATCHELLERVILLE DISTRICT.

The Batchellerville district is situated in Saratoga and Fulton Counties, its center being near Batchellerville. The feldspar of this district consists largely of a pearl-gray microcline pegmatite similar to that of the Ticonderoga district. The sea-green plagioclase is absent and the only soda feldspar present in independent masses is a few small lenses of a peculiar milk-white plagioclase, carrying about 4.50 per cent CaO and 8.50 per cent Na_2O. The feldspars contain small crystals of biotite, which is present in large amounts only in the capping material. Garnets are found in only one dike and not throughout the full extent of this deposit. Most of these pegmatites contain muscovite. A graphic granite structure was noted at several points in this district. One dike of salmon-colored feldspar occurs within this district and this feldspar was found on analysis to contain 14 per cent K_2O, which accounts for its temperature range of deformation, 1,280° to 1,300° C. The pegmatites have a lower quartz content and a lower average proportion of impurities than the New England pegmatites, and although not as uniform in composition as the New England feldspars the coarsely crystalline structure permits of a more complete elimination of the associate minerals than is possible in New England. The feldspars of this district are famous for their fine color and have been drawn on exclusively for use in raising the quality of the output from semiexhausted quarries in other districts. Lack of railroad facilities has been the chief drawback in the general development of the feldspar deposits of this district.

ANALYSES OF FELDSPARS FROM BATCHELLERVILLE DISTRICT.

Some representative feldspars of this district show the following analyses:

Analyses of feldspars of the Batchellerville district.

[Robert Back, analyst.]

Constituent.	Pearl-gray microcline.	Salmon microcline.	Plagioclase.
	Per cent.	*Per cent.*	*Per cent.*
Ignition loss..	0.26	0.17	0.54
SiO_2..........	65.14	64.26	61.91
Al_2O_3........	19.38	18.78	23.69
Fe_2O_3........	.29	.43	.40
TiO_2.........	.01	....	....
CaO..........	.44	.33	4.37
MgO..........	.14	.14	.13
BaO..........	....	....	....
K_2O..........	11.28	14.15	1.17
Na_2O.........	3.61	2.01	8.40

WESTCHESTER COUNTY DISTRICT.

The Westchester County district has comparatively narrow limits. It has its center in an enormous pegmatite dike of widely varying structure situated just east of Bedford village and includes numerous smaller dikes or stringers of this main dike, all within a radius of a few miles. The main dike consists of at least four distinct types of feldspar. The eastern part is a pink to salmon microcline almost free from quartz and associated with an albite pegmatite. Small lenses of a chalky white albite free from quartz are scattered through this part of the dike. The crystallization in these three types of feldspar is relatively coarse and their separation on a commercial scale is entirely practical. Biotite is associated with the soda feldspars in some parts of the deposit, but such parts could be easily eliminated in sorting. Many large lenses of sugar quartz occur in this dike.

To the west of the main deposit and at a level about 80 feet below it is an enormous lens of cream and dark buff microcline pegmatite, of much finer crystallization as regards feldspar and quartz, some parts of it being graphic granite. Biotite is associated with the feldspar of this lens, but can be eliminated by cobbing, and hence does not constitute a menace to the mining of the material for pottery feldspars. Albite pegmatite of good quality is also present in this part of the deposit. To the east of the main deposit are several small dikes of cream-colored microcline pegmatite which is coarsely crystalline, contains little albite, much massive sugar quartz, and no graphic granite.

Because of the great variety of feldspars in this district special caution is needed in mining and selection, otherwise a great variation in maturing temperatures and rate of deformation will result. If proper care is exercised, however, the district is capable of producing excellent grades of potash and soda feldspar, although the latter would contain a considerable amount of free quartz. The feldspars of this district have been drawn on in the past chiefly to supply the enamel and glass industries, and no effort has been made to meet the demand of the potter for a finely pulverized product absolutely free from coloring material.

PROPERTIES OF FELDSPARS FROM WESTCHESTER COUNTY DISTRICT.

The microcline both of the salmon and buff varieties fuses to a practically colorless glass and has a deformation range of 1,265° to 1,280° C. The albite pegmatite fuses to a milk white enamel and has a deformation range of 1,265° to 1,270° C., notwithstanding its high quartz content. The representative feldspars of this district show the following analyses:

Analyses of feldspars of Westchester County district.

Constituent.	Salmon microcline.[a]	Buff microcline pegmatite.[b]	Albite pegmatite.[a]
	Per cent.	*Per cent.*	*Per cent.*
Ignition loss	0.22	0.28	0.40
SiO_2	64.82	69.45	73.88
Al_2O_3	18.87	16.76	15.73
Fe_2O_3	.29	.20	.36
TiO_2	.01	None.	.01
CaO	.23	.45	.86
MgO	.16	.05	.36
BaO	Trace.	.10	
K_2O	13.11	9.80	.48
Na_2O	2.70	2.60	7.97
Total	100.41	99.69	100.05

[a] Robert Back, analyst. [b] D. J. Demorest, analyst.

PENNSYLVANIA.

The only feldspar producing district of Pennsylvania is situated west of Philadelphia in Delaware and Chester Counties, between the Delaware and the Susquehanna Rivers. Most of the quarries are within hauling distance of the Philadelphia, Baltimore & Washington Railroad. One deposit near Pomeroy, on the Pennsylvania Railroad, is also worked, but the output is sold exclusively as poultry grit.

The feldspars of Pennsylvania comprise two forms of microcline pegmatite and two of albite pegmatite. These feldspars have enjoyed excellent reputations for quality, but the large deposits have been exhausted and now operations are confined to smaller dikes and to the resorting of the rejects from the older workings. Not a single quarry in Pennsylvania is producing enough material at the present time (April, 1915) to operate a grinding mill, the products of several small quarries being purchased and delivered to a central mill which blends them.

The microclines of Pennsylvania may be divided into two general classes: (*a*) A buff microcline occurring as a pegmatite of medium coarse crystallization in most dikes, but occasionally occurring as a graphic granite; and (*b*) a salmon microcline occurring as small lenses in the buff pegmatite and in a few instances as the chief microcline constituent of an albite pegmatite dike. These two forms of microcline do not differ widely in composition, as indicated by the following analyses:

Analyses of Pennsylvania microclines.

[D. J. Demorest, analyst.]

Constituent.	Buff microcline.			Salmon microcline.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Ignition loss	0.33	0.30	0.21	0.12
SiO_2	64.40	63.68	64.36	64.70
Al_2O_3	20.22	19.93	20.01	19.60
Fe_2O_3	.06	.20	.20	.03
CaO	.06	.13	.46	.05
Na_2O	2.77	3.00	2.48	3.76
K_2O	12.62	12.22	12.44	11.87

The associate quartz is generally a pale smoky variety. Massive quartz as sugar quartz is less common in the microcline pegmatites of Pennsylvania than in those of New England and New York. Biotite is associated with the microcline in most deposits, but generally not to such an extent as to disqualify the dike material for pottery uses.

Garnets are also present in a few deposits, but are generally confined to limited zones which can be eliminated by careful mining.

All the microcline pegmatites contain muscovite in small flakes but the amount present in this form constitutes so small a percentage of the total mass that its injurious influence need not be considered. Where present as "books" or small blocks, it can generally be eliminated in sorting. The amount of block mica is not sufficient to afford any considerable income to the operator.

The albite pegmatite of Pennsylvania occurs in two distinct forms: One of these forms consists of intimately mixed albite and quartz and is similar to the microcline pegmatite except that the content of free quartz as a rule is greater and the feldspar is an opaque white, that of the microcline feldspar being a transparent or translucent white. The results of an analysis of a sample of the albite pegmatite follow.

Analysis of albite pegmatite.

[D. J. Demorest, analyst.]

	Per cent.
Ignition loss	0.42
SiO_2	74.60
Al_2O_3	15.66
Fe_2O_3	.05
TiO_2	.....
CaO	2.75
MgO	.....
Na_2O	6.33
K_2O	.65
	100.46

The high content of quartz in this type of soda pegmatite caused it to be rejected during the early years of feldspar mining in Pennsylvania, but as the pure feldspar masses became exhausted and the graphic granite came into use as a source of feldspar this soda pegmatite came into use also. Hence the feldspar of Pennsylvania that is marketed to-day has not only a higher quartz content, but it also contains more soda than the feldspar mined in the early years of operation in this district. As evidence of this analyses of three samples of potash feldspar taken from the same mill at intervals of three years are given here:

Analyses of samples of potash feldspar taken at 3-year intervals

[D. J. Demorest, analyst.]

Constituent.	Composition of sample.		
	1904	1907	1910
	Per cent.	*Per cent.*	*Per cent.*
Ignition loss	0.80	0.17	0.42
SiO_2	65.78	68.60	69.05
Al_2O_3	19.12	18.40	17.40
Fe_2O_3	....	.54	.15
CaO	.41	.30	.12
MgO	.12	.14	....
Na_2O	1.82	2.00	2.97
K_2O	11.91	10.52	10.03
Total	99.96	100.67	100.14

Another form of albite pegmatite peculiar to Pennsylvania and a small part of the State of Maryland immediately adjacent consists of lenses of practically pure albite coarsely mixed with a magnesium hydrosilicate. Bastin[a] refers to these as pegmatites but not in the sense that they are mixtures of feldspar and quartz, as these deposits contain no free crystalline quartz. The only other minerals intimately associated with the feldspar in these deposits are a dark

[a] Bastin, E. S., Economic geology of the feldspar deposits of the United States: U. S. Geol. Survey Bull. 420, 1910, pp. 68-72.

green hornblende and muscovite. The latter occurs only in small amounts; the hornblende is scattered throughout the deposits and must be carefully removed, because it imparts a dark color to the feldspar when fused. The enormous deposits of this albite in Chester County, for which this district has been justly famous, have been almost exhausted and operations are now confined to a few narrow dikes which are doubtless stringers of the main deposits.

Thus it seems that Pennsylvania has begun to decline as a feldspar producer, and unless new and extensive deposits of superior quality are found, the consumer must look elsewhere for at least a large part of the supply formerly obtained from this State.

MARYLAND.

Maryland's feldspar producing area lies along the line of the Baltimore & Ohio Railroad in Howard and Baltimore Counties. The quality of feldspar obtained from Maryland quarries varies greatly, but this is due both to the methods employed in working the deposits and to the nature of the deposits themselves. In some places the dikes are so weathered that the material is forked over to separate the solid feldspar from the dirt, in a manner similar to that employed in recovering the feldspar from the old quarry dumps in Pennsylvania, but in most places, however, the dike rock is solid. The feldspar is both microcline and albite pegmatite. The microcline pegmatite contains cream and buff feldspar similar in appearance to that of Pennsylvania, but analyses indicate a slightly higher alumina and lower silica content. The quartz content varies greatly for different pegmatites but does not vary excessively throughout any given deposit.

The albite pegmatite of Howard and Baltimore Counties is a chalky white albite or plagioclase mixed with quartz of a faint smoky variety. The feldspar component of this pegmatite does not differ from that of similar deposits in Pennsylvania, but the proportion of albite pegmatite as compared to the microcline variety is much higher in Maryland deposits than in those of Pennsylvania, and hence a more easily fusible pottery feldspar should be obtained from this district than from Pennsylvania.

The greatest obstacle to obtaining high grade feldspar in Maryland is biotite, which occurs in a majority of the dikes in tiny flakes. Its removal is imperative if an acceptable pottery feldspar is to be produced.

Samples of feldspar representing the average of these minerals in Maryland show the following analyses.

Analyses of Maryland pegmatites.

[D. J. Demorest, analyst.]

Constituent.	Microcline pegmatite.		Albite pegmatite.
	A.	B.	C.
	Per cent.	*Per cent.*	*Per cent.*
Ignition loss	0.39	0.13	0.76
SiO_2	65.75	74.20	65.32
Al_2O_3	19.48	14.30	22.00
Fe_2O_3	.20	.20	.21
TiO_2			
CaO			3.78
MgO			
Na_2O	1.87	1.59	6.89
K_2O	11.33	9.48	1.06
Total	99.02	99.90	100.02

Small quantities of pure albite pegmatite associated with magnesium hydrosilicate are found in Cecil County along the boundary of Pennsylvania, which are in every way similar to those in Chester County. No deposits of pure albite of commercial size are now open in Maryland and no undeveloped dikes of this class of material are known to exist in that State.

The pegmatite dikes of Maryland have not been operated extensively until very recently, and if care is taken to insure a high-grade product this State can provide much of the feldspar supply which was formerly obtained in Pennsylvania.

VIRGINIA.

Feldspar occurs at numerous points in Virginia, but the actual production has been very small and all the operations have been very short lived. Most of the feldspar found in Virginia has been exposed in mica mines and the methods of mining were not adapted to the economical recovery of the feldspar. Dikes of feldspar have been thus exposed at Jetersville and Amelia Courthouse, Amelia County, and near Hewletts, Hanover County, but the extent of these deposits has never been determined. They all consist of coarse mixtures of microcline and albite of excellent quality with very little associated quartz, although massive sugar quartz is abundant along the walls of the dikes.

In Prince Edward County and in Bedford County a coarse pegmatite is found which should yield a good grade of commercial feldspar. Both of these deposits were worked for a short time only and operations were discontinued although there is no evidence of the deposits being worked out. The dike in Bedford County is exposed over a considerable area and an analysis shows it to be a good mixed feldspar of the following composition:

Analysis of feldspar from dike in Bedford County.

[D. J. Demorest, analyst.]

	Per cent.
Ignition loss	0.10
SiO_2	68.75
Al_2O_3	18.56
Fe_2O_3	.03
CaO	1.25
Na_2O	4.29
K_2O	6.85
Total	99.83

Near Roseland, Nelson County, a broad dike of albite and albite pegmatite carrying a high content of rutile and ilmenite is being worked for rutile. A part of this dike along the north wall contains hornblende and its separation from the feldspar would be difficult, but if carefully mined a great part of the feldspar that does not contain much hornblende could be made marketable after removing the rutile and ilmenite. This feldspar should find a market in the industries and replace in part the shortage of albite.

NORTH CAROLINA.

The feldspar deposits of North Carolina are distributed throughout the mountain section southeast of the Great Smoky Mountains. The most promising districts are those described in Bulletin 53 of the Bureau of Mines [a] as the Cowee district and the Sprucepine district. The former includes parts of Jackson, Macon, and Swain counties and the latter includes parts of Yancey, Mitchell, and Avery counties. The feldspars throughout this State are as a rule cream white microclines with very low soda content. A few small deposits of soda feldspar and anorthoclase were noted but the great majority of deposits in North Carolina are of potash feldspar, most of it being extremely coarse pegmatite, and, as the field is new, a large amount of pure feldspar is to be found as lenses in the pegmatite. Many of the pegmatites are so coarsely crystalline that the quartz content can be almost entirely removed by cobbing. The dikes are seldom large, however, and as most of them stand almost vertical, the problem of mining is more difficult than where the deposits are large lenses or lie nearly flat, as is the case with many deposits farther north. The chief impurities are quartz and muscovite, with smaller amounts of biotite, beryl, and garnets. The latter three minerals, however, are seldom present in quantity sufficient to affect injuriously the color of the product, and the muscovite is generally coarsely crystalline and not generally distributed throughout the entire mass.

[a] Watts, A. S., Mining and treatment of feldspar and kaolin in the southern Appalachian region: Bull. 53, Bureau of Mines, 1913, p. 12.

The mining in the Cowee district is confined to mining for mica and no attempt is made to remove the feldspar except where it interferes with the mining of the mica. In the Sprucepine district, three feldspar quarries are now in operation and others are to be opened in the near future. The potash feldspars of North Carolina may be safely represented by the following analyses:

Analyses of potash feldspars of North Carolina.

[D. J. Demorest, analyst.]

Constituent.	A.	B.	C.	D.	E.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Ignition loss	0.90	0.17	0.60	0.30	0.40
SiO_2	64.48	65.37	63.90	65.68	64.93
Al_2O_3	19.43	17.92	19.97	19.08	19.45
Fe_2O_3	.01	.02	.15	.14	
CaO		.17	.05		.05
MgO					
BaO			.70		
K_2O	13.19	13.05	13.20	13.09	12.46
Na_2O	1.84	2.10	1.01	2.08	2.54
Total	99.85	98.80	99.58	100.37	99.83

GEORGIA.

Feldspar-bearing dikes have been found in various parts of Georgia, and the Geological Survey of Georgia has now under way an investigation of these deposits, but as yet no feldspar quarrying has been attempted in the State.

QUALITY OF THE PRODUCT.

The foregoing sets forth the general location and extent of the known feldspar deposits east of the Mississippi River.

In estimating the relative value of a feldspar and its adaptability to the various arts and industries due consideration must be given to the methods employed in the mining, refining, and pulverizing of the crude rock. For example, the feldspars of Maine are not naturally very pure; in fact, no feldspar produced in the United States has so many injurious associate minerals as that of Maine. Nevertheless, the Maine feldspars are furnished to the consumer in a state of purity second to none, except for the quartz content, which can not be eliminated and which must of necessity increase with continued mining in any district. This high state of purity is obtained only by untiring vigilance on the part of the miner and the mill operator to insure the removal of even the smallest particle of iron-bearing impurity and, having freed the crude feldspar of all such impurity, to prevent any contamination during the milling process.

The extra precautions necessary to insure such purity must of necessity increase the cost of the finished product. Not only must extra expense be incurred in handling and storing the crude feldspar before it goes to the mill, but many labor-saving and highly efficient machines must be condemned because of their metal surfaces which come in contact with the sharp edges of the feldspar rock, and being ground off add an almost inappreciable content of iron to the finished product.

Inability to employ many modern machines and appliances has resulted in the general condemnation of the feldspar mining and grinding industry as unwilling to utilize modern appliances, but until machinery can be provided with all wearing faces made of material which will not contaminate the product the operator is to be commended rather than condemned for refusing to employ them.

A point which must be recognized by both the producer and the consumer of ground feldspar is the relation between the quality of the feldspar and the market price. The rejection of any proportion of the rock quarried requires that the accepted rock must be marketed at a price which will cover the expense of the entire quantity quarried unless the rejected material can be disposed of without loss in some other way. As the selection of the more choice parts continues, the amount of material handled continues to increase and this will ultimately result in increasing the cost of the finished product. It is therefore vitally important that every user of feldspar should have a proper understanding of the degree of purity which his business demands and, having done so, seek that grade of material where it can be obtained at the best advantage.

THE COLOR OF FELDSPARS.

The general opinion prevails that the small amounts of impurities which cause a natural feldspar to be cream, buff, brown, or salmon are lost in the fusing process, and that a dark feldspar may fuse to as perfect a white glass as a pure white feldspar. This is not true so far as the results of this investigation have indicated. The intensity of color in the fresh feldspar is, however, no indicator of the intensity of color in the fused feldspar nor of its coloring action in the pottery body or glaze.

In general the feldspars which fuse to the most colorless or white glasses are those which are pure white or colorless. The next in order are the pale salmon and nearly transparent feldspars; then come the cream feldspars, which are generally opaque, or nearly so; the next are the brown and buff feldspars; and the last and most highly colored when fused are the sea-green or olive-green brown feldspars.

This classification is for feldspars which do not contain any foreign material other than that distributed uniformly as a colorant through the entire mass.

The range of tints obtained within the variation of natural feldspars, with the exception of the olive or sea green feldspars, are only possible of detection where the materials are prepared with the utmost care. Any dirt or dust on the surfaces of the crude feldspar or carelessness in the crushing or grinding process may result in a fused product of a color far inferior to any obtainable by fusing the darkest colored natural feldspar, the olive-green or sea-green feldspars excepted.

The problem, then, resolves itself into one not entirely of obtaining the feldspar of the best natural color, but more especially of guarding against the introduction of impurities naturally associated with the feldspars and also of impurities which may be introduced in the milling.

Plates II and III show the range of color in the natural feldspars.

DESCRIPTION OF SPECIMENS SHOWN IN PLATES II AND III.

In the following list are described the specimens shown in Plates II and III. All of the feldspars shown in Plates II and III, except H and L (Pl. III), fuse to white or colorless glass.

A. Microcline from Carolina Mineral Co. quarry, at Penland, Mitchell County, N. C. For a description of this deposit see location 110, Bureau of Mines Bulletin 53, page 100.

B. Microcline from Johnson mica mine, near Plumtree, Avery County, N. C. For a description of this deposit see location 106, Bureau of Mines Bulletin 53, page 112.

C. Microcline from Barrett quarry, Essex County, N. Y. For a description of this deposit see location 59, page 133.

D. Green microcline from Rutherford mica mine, Amelia County, Va. For a description of this deposit see location 110, page 167.

E. Albite from Sylmar quarry, Chester County, Pa. For a description of this deposit see location 89, page 156.

F. Microcline from Rhodes quarry, northeast of Northville, Fulton County, N. Y. For a description of this deposit see location 64, page 139.

G. Microcline from Kinkel quarry, near Bedford, Westchester County, N. Y. For a description of this deposit see location 68, page 142.

H. Greenish brown microcline from Berry quarry, Auburn, Androscoggin County, Me. For a description of this deposit see location 40, page 122.

I. Transparent albite from Saunders, near Hewletts, Hanover County, Va. For a description of this deposit see location 114, page 169.

J. Microcline from old Perry quarry, Phippsburg Peninsula, Sagadahoc County, Me. For a description of this deposit see location 21, page 110.

K. Microcline from old Claspka quarry near Batchellerville, Saratoga County, N. Y. For a description of this deposit see location 63, page 137.

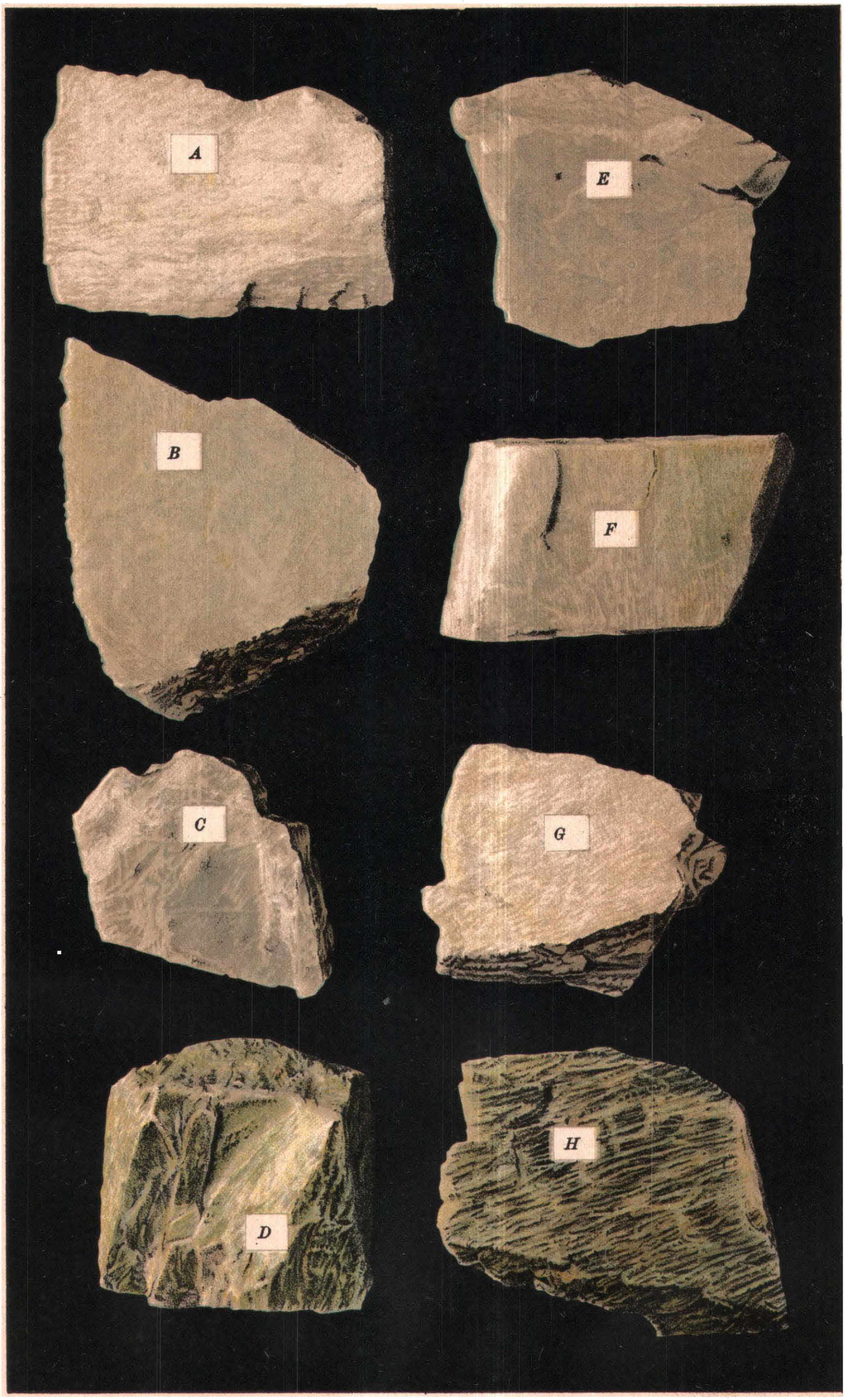
L. Andesine from Crown Point quarry, Essex County, N. Y. For a description of this deposit see location 58, page 132.

M. Microcline from Eureka quarry, Portland, Middlesex County, Conn. For a description of this deposit see location 50, page 127.

N. Microcline from Claspka quarry near Batchellerville, Saratoga County, N. Y. For a description of this deposit see location 62, page 136.

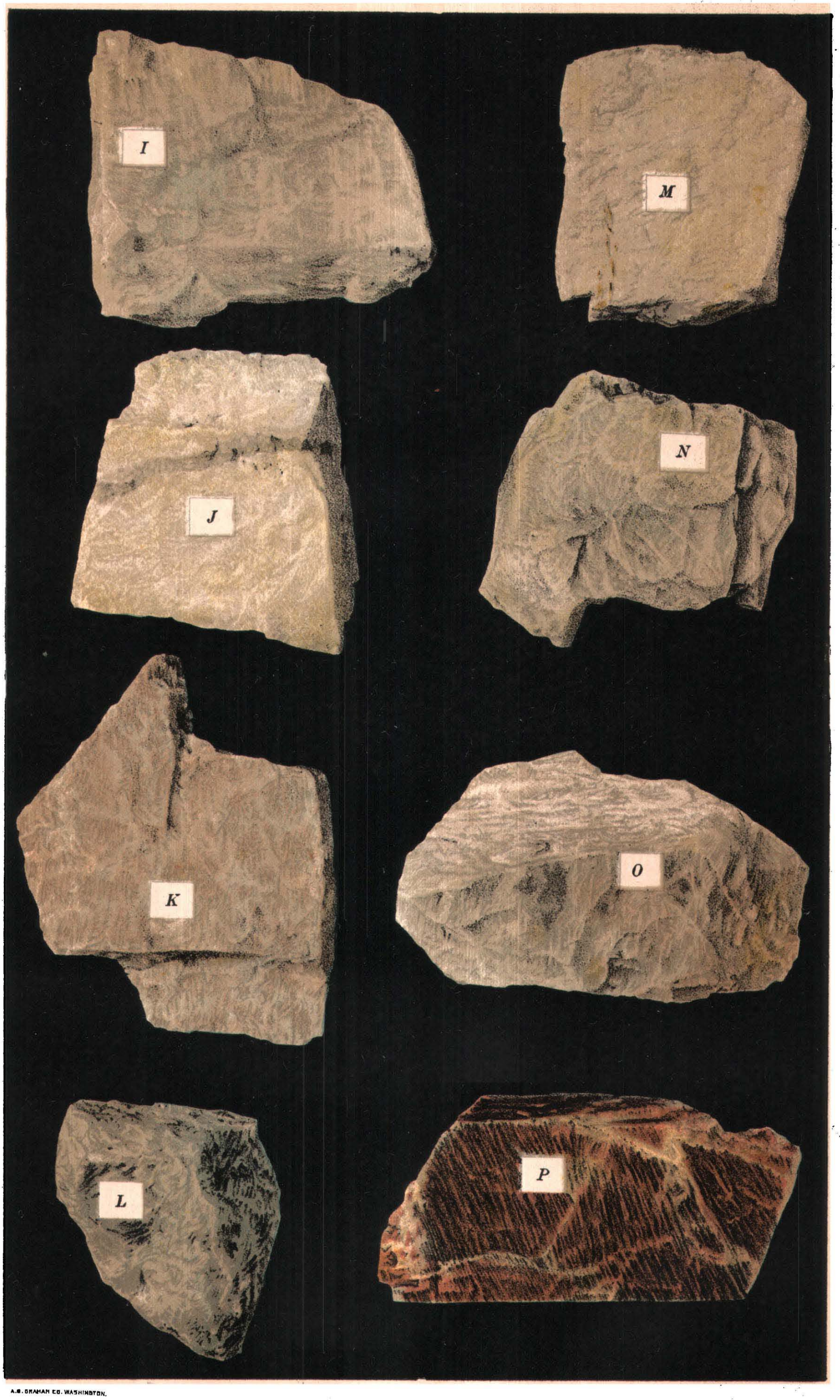
O. Microcline from Tyrol Mountain quarry southwest of Northville, Fulton County, N. Y. For a description of this deposit see location 66, page 140.

P. Microcline from Richardson quarry, Godfrey, Ontario, Canada.



A. B. GRAHAM CO., WASHINGTON.

MICROCLINE AND ALBITE IN NATURAL COLORS.
FOR DESCRIPTION SEE ACCOMPANYING TEXT.



A. B. GRAHAM CO. WASHINGTON.

ANDESINE, MICROCLINE, AND ALBITE IN NATURAL COLORS.
FOR DESCRIPTION SEE ACCOMPANYING TEXT.

MINERALS ASSOCIATED WITH FELDSPAR IN PEGMATITE.

A knowledge of the minerals associated with feldspar in pegmatite is essential if a proper estimation of the value of the dike material is to be arrived at.

The chief minerals associated with the feldspar in pegmatite are quartz, muscovite (white mica), biotite (black mica), garnets, beryl, tourmaline, magnetite.

Although pegmatites are essentially coarsely crystalline mixtures of feldspars and quartz, the associated minerals other than quartz are important as their amount and the mode of their occurrence have a vital influence on the industrial value of the pegmatite.

QUARTZ.

Quartz is an essential mineral of pegmatite and may be either mixed with the feldspar or intercrystallized with it as graphic granite; most pegmatite dikes also contain intruded lenses or bands of quartz that differ in texture and appearance from ordinary pegmatite quartz. This quartz has a granular structure in most deposits and is commonly known as sugar quartz. It is white or pink in color and is opaque or semiopaque, owing to fracture planes and to minute bubbles of gases, principally water vapor, that have been entrapped in the solidifying silica. In the smoky quartz of pegmatite these bubbles also contain organic material, and this causes the dark smoky color.

These masses of quartz are oftenest found along the walls of the dike, where the shrinkage of dike material in solidifying formed cracks in which this silica was deposited. The occurrence of lenses of sugar quartz completely separated from the walls and often in the very center of the dike are doubtless due to temporary crevices in the lower parts of the pegmatite mass. In a vast majority of cases, the masses of sugar quartz included within the pegmatite are found to communicate by stringers with quartz bands along the walls.

MUSCOVITE.

Muscovite (white mica) is a constituent of nearly every pegmatite. Crystals of this mineral occur in all sizes from 3 feet in diameter to tiny flakes which require a microscope to identify them. Muscovite in large crystals or in aggregates known as "books" is generally found between bands near the walls or imbedded in a comparatively narrow band of highly mineralized material adjoining the walling quartz. The continuation of muscovite in quantity between any given bands of a dike is uncertain; a rich muscovite bearing band may suddenly pinch out or disappear along one wall of a dike and reappear between two bands near the center of the dike, or may even be transferred to the band adjoining the quartz or the wall band on the opposite side of the dike. Where the dike rock is not in distinct bands or the pegmatite is only moderately coarse the muscovite is often present in fine flakes, which are distributed throughout the entire mass. In the latter case its separation from the feldspar is difficult and often impossible except at a great sacrifice of feldspar.

BIOTITE.

Biotite (black mica) is an associate mineral of nearly all pegmatite, but its mode of occurrence is not similar to that of muscovite. Biotite is generally present as a chief constituent or is practically absent. Its commonest form is in lathlike crystals, which often are 3 feet in length and 4 to 6 inches in diameter, but the thickness rarely exceeds one-fourth of an inch. Such crystals are in many places matted together with smaller crystals in a pegmatite, rendering that part of the deposit too impure to justify sorting by hand. Fortunately, such masses are often associated with masses practically free from biotite; hence its presence in coarse crystals need not condemn the entire deposit. Where biotite occurs as crystals less than 1 inch in maximum dimension it is generally distributed throughout the mass and its complete separation is impracticable. Owing to the brittleness of biotite it breaks and becomes a powder under treatment which would not shatter the more elastic muscovite and hence is even more difficult to remove than muscovite. Such pegmatite can be utilized in the industries where a white-burning feldspar is not required.

GARNET.

Garnet is a common constituent of pegmatite and is one of the most annoying minerals with which the feldspar producer has to deal. The garnet crystals are often so tiny as to escape any but the closest scrutiny. Only in rare cases are they of sufficient size to permit of removal by cobbing, and as even a few coarse crystals indicate the presence of many smaller ones, the finding of garnets in a pegmatite is with many operators sufficient cause for doubting its quality.

The process of sorting material from a dike containing scattered garnet-bearing masses is laborious and expensive and too often unprofitable. The rock must be broken to small size and all of it carefully sorted by hand.

In dikes of a pronounced banded structure the garnets are often confined to one or two bands, and where such is the case they can be eliminated by rejecting these bands.

Garnet generally occurs as andradite (calcium iron silicate) of the approximate composition $3CaO.Fe_2O_3.3SiO_2$, and its coloring power in feldspar is very great. An addition of 1 per cent of garnet to feldspar that fuses to milky white causes it to fuse to an intense yellow brown, and the presence of one-tenth of 1 per cent of garnet would render a feldspar unmarketable as a pottery feldspar. Garnet grinds at about the same rate as feldspar, and its presence in a feldspar imparts a faint flesh tint to the powdered rock. As many feldspars are naturally flesh colored, the presence of garnet can not be detected by this color and generally is not suspected until it is shown by the mass fusing to a yellow color in finely pulverized feldspars or by brown specks in coarsely ground feldspar.

BERYL.

Beryl occurs chiefly in pegmatite rich in feldspar, and the beryl crystals, which are hexagonal, are generally imbedded in masses of pure feldspar.

Although beryl may be golden, blue, green, or even pink, the vast majority of the beryl crystals in pegmatite are pale blue with a vitreous luster. The wide variety of tints in feldspar and its similar luster makes it very difficult to distinguish beryl from feldspar, except where a face of the beryl crystal is exposed. Beryl is notably harder than feldspar and generally has a conchoidal fracture, but as most massive feldspar breaks irregularly, the faces exposed resemble conchoidal fractures in many instances. If the crude material was not reduced by too powerful a crusher, the beryl, being harder, could doubtless be largely removed, but to eliminate it from pulverized rock would be impossible. The only practical means of separating beryl from crude feldspar is to carefully scrutinize the rock in the quarry, and wherever beryl is detected to watch for it after each blast and sort the beryl-bearing rock from the marketable feldspar.

Beryl has the composition $3BeO.Al_2O_3.6SiO_2$. It does not discolor the fused feldspar but makes it opaque and in small amounts it lowers the deformation temperature of the feldspar. Its chief disadvantage is its tendency to reduce the translucency of the ware.

TOURMALINE.

Tourmaline usually occurs in pegmatite rich in feldspar and containing very little biotite. It is commonly black, although pink, green, blue, and colorless crystals are occasionally found, and furnish gems when transparent. Tourmaline as a rule is in the form of irregular rods, 3 to 15 inches long and one-half inch to 3 inches in diameter, imbedded in the feldspar. Being black, it is easily detected and its complete removal is imperative if the feldspar is to be marketed for pottery uses.

Tourmaline has a very complex and variable composition of approximately $3R_2O.SiO_2$, in which R may represent a mixture of aluminum, boron, magnesium, and iron compounds and alkalies or any of them.

MAGNETITE.

Magnetite or black oxide of iron is sometimes found in pegmatite. Its presence absolutely condemns the feldspar for ceramic uses because the particles of magnetite are usually almost microscopically small so that the sorting of such material is extremely expensive. Attempts to remove the magnetite by means of electromagnets have failed because of the difficulty of separating the feldspar and magnetite by any system of rolls or crushers.

Magnetite has the composition Fe_3O_4 and its presence in the pulverized feldspar is evidenced by minute black specks. In the fused feldspar the magnetite shows as black specks surrounded by yellowish or brownish zones of ferric silicate.

GENERAL COMPOSITION OF THE MARKETED PRODUCT.

In general a pegmatite must have a comparatively high feldspar content if its quarrying for feldspar is to be profitable under ordinary conditions.

The average pegmatites being marketed as feldspar contain about 80 per cent of feldspar. The other 20 per cent is principally quartz, as the presence in appreciable quantity of any mineral which might discolor the ware would result in the condemnation of the entire output of a quarry.

FELDSPAR CLASSIFICATION.

Feldspars may be classified according to their alkali constituent into four distinct groups:

Potash feldspars, known as microcline or orthoclase, $KAlSi_3O_8$.

Soda feldspar, known as albite, $NaAlSi_3O_8$.

Lime feldspar, known as anorthite, $CaAl_2Si_2O_8$.

Barium feldspar, known as celsian, $BaAl_2Si_2O_8$.

In nature these minerals are rarely found in the pure state, but commonly occur as intimately crystalized masses of two or more different feldspars. Some of the feldspars apparently combine and form homogeneous crystals of definite composition, whereas others are isomorphous mixtures.

Iddings[a] reports the following varieties as having been recognized:

Soda-orthoclase $(KNa)AlSi_3O_8$.

Anorthoclase or soda-microcline, $NaKAlSi_3O_8$.

Plagioclase or lime-soda feldspar series $\begin{cases} n(NaAlSi_3O_8). \\ m(CaAl_2Si_2O_8). \end{cases}$

Hyalophane or barium-potash feldspar $\begin{cases} n(KAlSi_3O_8). \\ m(BaAl_2Si_2O_8). \end{cases}$

[a] Iddings, J. P., Rock minerals, 1911, p. 205.

In the plagioclase series the ratio of soda feldspar to lime feldspar may vary from $\frac{\text{6 molecules soda feldspar}}{\text{1 molecule lime feldspar}}$ to $\frac{\text{1 molecule soda feldspar}}{\text{6 molecules lime feldspar}}$. Soda-lime feldspars containing less than 1:6 ratio are classified with the pure feldspar which they approach.

The hyalophane series, as classified by Rosenbusch,[a] comprises such barium-potash feldspars as contain between 7.5 and 16.4 per cent BaO. Those potash feldspars which contain less than 7.5 per cent BaO are called orthoclase and those which contain more than 16.4 per cent BaO are classed as celsian.

POTASH FELDSPARS.

Potash feldspar is found in nature in two forms—namely, microcline, which is the chief constituent of the ordinary feldspar of commerce, and orthoclase, which is less frequently met with, although until recently the microcline of commerce has gone by this name. The error has, however, been of no industrial importance because the two minerals are identically the same in chemical composition, differing only in crystalline form and in optical properties.

Microcline has the molecular formula $K_2OAl_2O_36SiO_2$ and is approximately of the composition K_2O, 16.9 per cent; Al_2O_3, 18.4 per cent; and SiO_2, 64.7 per cent; its specific gravity is 2.54; it has a hardness of 6 to 6.5; and belongs to the triclinic system. Its color is generally white, grayish yellow, yellow, or any shade of red from light rose to brick color, the red color being due to finely divided iron oxide or hydroxide. It may be green (amazon stone) in transmitted light. In thin sections it is colorless. The Na_2O content varies up to 4 per cent and that of the CaO seldom exceeds 05 per cent.

As the microclines which are richest in Na_2O and CaO are also mechanically mixed with the largest amounts of albite and oligoclase-albite, it is not improbable that Na_2O and CaO do not belong to the true microcline molecule. As the Na_2O content increases in a microcline the specific gravity increases and with a soda content of 4 per cent may be as much as 2.57.

Orthoclase varies in few respects from microcline. It crystallizes in the monoclinic system, but the polysynthetic twinning that is characteristic of microcline may be submicroscopic in orthoclase and hence not apparent. It has the same specific gravity and color as microcline, and has a hardness of 6.

[a] Rosenbusch, K. H. F., Mikrokopische Physiographie der Mineralien und Gesteine, Bd. 1, Heft 2, 1908, p. 309-313.

SODA FELDSPARS.

Soda feldspar is found in nature in two forms—namely, albite, which is the form ordinarily encountered, and cleavelandite, which is a lamellar variety of albite, differing from it only in massive structure and having the same optical and physical properties.

The molecular formula of albite is $Na_2O.Al_2O_3.6SiO_2$. Its approximate composition is as follows: Na_2O, 11.8 per cent; Al_2O_3, 19.4 per cent; SiO_2, 68.8 per cent. Albite has a specific gravity of 2.624, ranges in hardness from 6 to 6.5, and crystallizes in the triclinic form. Its color is generally white, although it may be reddish, greenish, bluish, or gray. Cleavelandite often displays a bluish tint. In thin sections albite is colorless.

The Na_2O in albite may be replaced by CaO in amounts less than 3 per cent CaO and the mineral still retain its name. When the CaO content exceeds 3 per cent, however, it is classified as a lime-soda feldspar, of which there are now recognized a series of five numbers between pure albite and pure anorthite. These form the plagioclase subgroup.

LIME FELDSPAR.

Lime feldspar is known as anorthite and in its pure state occurs only in one form. This feldspar has the molecular formula $CaO.Al_2O_3.2SiO_2$, and contains the following percentages of these compounds: CaO, 20.1; Al_2O_3, 36.62; and SiO_2, 43.28 per cent. The mineral has a specific gravity of 2.758, a hardness of 6 to 6.5, and belongs to the triclinic system. It is white, grayish, or reddish, but is colorless in thin sections.

The CaO in anorthite may be replaced by Na_2O in amounts less than 1.6 per cent. When the Na_2O content exceeds 1.6 per cent the feldspar becomes one of the plagioclase subgroup.

BARIUM FELDSPAR.

Barium feldspar is known as celsian and in the pure state occurs only in one form. The molecular formula of celsian is $BaO.Al_2O_3.2SiO_2$. The mineral contains 41.8 per cent BaO, 27.2 per cent Al_2O_3, and 32 per cent SiO_2, and has a specific gravity of 3.38, a hardness of 6 to 6.5; crystallizes in monoclinic form, and is colorless unless stained by impurities.

FELDSPAR SERIES.

Aside from these four principal feldspars, there are many feldspars which are made up of two fluxes.

Anorthoclase or soda-microcline is a feldspar in which more than one-half the potash is replaced by soda.

Hyalophane is a feldspar in which part of the potash is replaced by barium.

Plagioclases are lime-soda feldspars which are a group of feldspars whose members form a continuous series connecting albite and anorthite, as may be seen from the following table:

Feldspars, their formulas and limits of composition.[a]

Name.	Formula limits.	Limits of composition.					
		BaO.	K_2O.	Na_2O.	CaO.	Al_2O_3.	SiO_2.
Celsian	$BaAl_2Si_2O_8$	40.8	....	....	....	27.2	32.0
	$(BaAl_2Si_2O_8)\ 2\ (KAlSi_3O_8)$	16.5	10.1	....	....	21.9	51.5
Hyalophane	$(BaAl_2Si_2O_8)\ 2\ (KAlSi_3O_8)$	16.5	10.1	....	....	21.9	51.5
	$(BaAl_2Si_2O_8)\ 6\ (KAlSi_3O_8)$	7.5	13.8	....	....	20.0	58.7
Microcline or orthoclase.	$KAlSi_3O_8$	....	16.9	....	....	18.4	64.7
Anorthoclase	$(2KAlSi_3O_8)\ 3\ (NaAlSi_3O_8)$	....	7.0	6.9	....	19.0	67.1
	$(KAlSi_3O_8)\ 6\ (NaAlSi_3O_8)$	....	2.5	10.1	....	19.3	68.1
Albite	$NaAlSi_3O_8$	....	....	11.8	....	19.4	68.8
Oligoclase	$6(NaAlSi_3O_8)\ (CaAl_2Si_2O_8)$	....	....	10.0	3.0	22.1	64.9
	$2(NaAlSi_3O_8)\ (CaAl_2Si_2O_8)$	....	....	7.7	7.0	25.4	59.9
Andesine	$3(NaAlSi_3O_8)\ 2\ (CaAl_2Si_2O_8)$	....	....	6.9	8.3	26.5	58.3
	$4(NaAlSi_3O_8)\ 3\ (CaAl_2Si_2O_8)$	....	....	6.6	8.9	27.0	57.5
Labradorite	$(NaAlSi_3O_8)\ (CaAl_2Si_2O_8)$	....	....	5.7	10.3	28.3	55.7
	$(NaAlSi_3O_8)\ 2\ (CaAl_2Si_2O_8)$	....	....	3.8	13.7	31.1	51.4
Bytownite	$(NaAlSi_3O_8)\ 3\ (CaAl_2Si_2O_8)$	....	....	2.8	15.3	32.5	49.4
	$(NaAlSi_3O_8)\ 6\ (CaAl_2Si_2O_8)$	....	....	1.5	17.4	34.3	46.8
Anorthite	$CaAl_2Si_2O_8$	....	....	....	20.1	36.6	43.3

[a] Formulas are according to Rosenbusch, Mikrokopische Physiographie der Mineralien and Gesteine. Authorities do not agree as to the exact formula limits, but the differences are negligible in most cases.

The above formulas represent only the pure minerals and combinations of two pure minerals. In nature one rarely finds a pure feldspar—that is, one containing but one alkali—in large quantity, and feldspars consisting of mixtures of but two pure minerals are comparatively rare. The manufacturer therefore has little use for data based on the pure minerals except as it conduces to a better understanding of the complex feldspars with which he has to deal.

The feldspars most extensively used in the industries are the two forms of potash-feldspars, microcline and orthoclase. The chemical compositions and physical properties of these two minerals are identical, and for all practical purposes they may be dealt with as one mineral, microcline, which is the form generally encountered.

In commerce the term "potash feldspar" is used in referring to any feldspar in which potassium is the prevailing flux, and even though the proportion of potassium is so low as to make the chemical composition approach hyalophane or anorthoclase, the latter names have never been employed in the industries.

As indicated in the above list, no series of feldspars occurs in nature in which the potash is replaced by lime, and if a potash feldspar contains any appreciable amount of CaO it is safe to assume that it contains an equal or greater amount of Na_2O, the two elements being introduced in one of the plagioclases, which is perthitically intergrown in the microcline.

Hyalophane is rarely encountered in commercial quantity. Barium as a constituent of feldspars is not uncommon but rarely exceeds 0.5 per cent and generally, if present, the proportion is less than 0.25 per cent. A study of the action of barium in feldspars has not been attempted in connection with this investigation, because the feldspars of the district contain little or no barium. However, it is a matter of record that potash feldspars which contain even a small amount of barium display a marked decrease in viscosity when fused, as compared with similar feldspars which contain no barium.

Mixtures of microcline and albite or mixtures of microcline and albite-rich members of the plagioclase series are really the feldspars with which the manufacturer who uses the material popularly known as "potash feldspar" has to deal.

In purchasing "soda feldspar" the manufacturer never obtains pure albite because deposits of pure albite of commercial size do not exist. The nearest approach to pure albite which is obtainable in commercial quantity is a feldspar high in soda content and relatively low in potash and lime content.

The impression prevails among users of feldspar that "soda feldspar" or albite is the softest member and "potash feldspars" or microcline is the hardest member of a feldspar series, and that the hardness of any mixture of these two will be proportionate to its relative content of the two extremes; that is, the deformation-temperature curve of potash feldspar-soda feldspar mixtures is supposed to be a straight vertical line with soda feldspar as the lowest point and potash feldspar as the highest point.

The results of a study by the writer of a large number of feldspars containing both potash and soda as fluxes indicates that this assumption is not true, but in making feldspar analyses there are so many slight variables which may affect the result that the exact cause of variation in any particular property is extremely difficult to determine. However, it was noted that feldspars with a moderately high content of soda and a proportionately low content of potash showed a marked tendency to deform at lower temperatures than did the relatively pure soda feldspars, as is shown by the following analyses of feldspars, arranged in the order of their deformation:

Feldspars classified in the order in which they deform.

Constituent.	Order of deformation and composition.		
	No. 1.	No. 2.	No. 3.
	Per cent.	*Per cent.*	*Per cent.*
H_2O	0.30	0.10	0.20
SiO_2	65.40	68.75	68.18
Al_2O_3	20.70	18.56	20.12
Fe_2O_3	.10	.03	.05
CaO	1.60	1.25	.85
MgO	Trace.	Trace.	.05
K_2O	6.00	6.85	.66
Na_2O	6.10	4.29	9.38
Total..	100.20	99.83	99.49

The ordinary conception would lead to the assumption that No. 3 is the most easily fusible of the three instead of being the least fusible, as it really is.

EFFECT OF COMPOSITION ON PROPERTIES OF FELDSPAR.

DEFORMATION TESTS OF POTASH FELDSPAR-SODA FELDSPAR MIXTURES.

In order to determine the most fusible mixture of potash and soda feldspars, a series of mixtures of these two feldspars was prepared and deformation studies made.

The feldspars used in preparing the series of mixtures had the following composition:

Composition of feldspars employed.

	H_2O.	SiO.	Al_2O_3.	Fe_2O_3.	TiO_2.	CaO.	MgO.	K_2O.	Na_2O.	BaO.
	Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
Potash feldspar......	0.50	64.3	19.64	0.08	Trace.	Trace.	Trace.	14.00	1.32	0.17
Soda feldspar.........	.20	68.18	20.12	.05	...do..	0.85	0.05	.66	9.38	....

Neither of the above feldspars is a pure type, each of them being a mixed feldspar that was high in the particular feldspar sought.

Unfortunately, in all the large feldspar deposits the feldspar contains less than the theoretical amount of alkali, although as a rule the ratio of Al_2O_3 to SiO_2 closely approaches the theoretical if the free quartz in the pegmatite is removed. This shortage of alkali is doubtless due to slight alteration of the feldspar, but no information is available pointing to the formation of products other than kaolin by the weathering of feldspar.

To subdivide an ordinary feldspar into its possible mineral components by a process of calculation based upon its alkali content results in confusion, as an excess of Al_2O_3 and SiO_2 remains after all possible minerals have been deducted. The absence of sufficient combined water makes it impossible to calculate the excess Al_2O_3 into kaolin, although the Al_2O_3 must be in other than the free state because none dissolves in hydrochloric acid.

As the feldspars used in this investigation must be divided into microcline and albite content, the ratio of K_2O to Na_2O has been chosen as the basis of division after that amount has been deducted which can be calculated as kaolin, the combined water being used as the basis of this latter calculation.

The result of this subdivision is as follows:

Composition of feldspars on basis of microcline, albite, and kaolin content.

	Microcline.	Albite.	Kaolin.
	Per cent.	*Per cent.*	*Per cent.*
Potash feldspar..	85.0	11.5	3.5
Soda feldspar....	4.5	94.0	1.5

The mixtures of these two feldspars as used in the investigation are as follows:

Mixtures of feldspars used.

Proportions in mixture.		Approximate normal constitution.	
		Albite.	Microcline.
	Per cent.	*Per cent.*	*Per cent.*
Soda feldspar.....	100	94	4.5
Soda feldspar.....	90	16	12.5
Potash feldspar...	10		
Soda feldspar.....	80	77.5	21.0
Potash feldspar...	20		
Soda feldspar.....	70	69.0	29.0
Potash feldspar...	30		
Soda feldspar.....	60	61.0	37.0
Potash feldspar...	40		
Soda feldspar.....	50	53.0	45.0
Potash feldspar...	50		
Soda feldspar.....	40	44.5	53.0
Potash feldspar...	60		
Soda feldspar.....	30	36.0	61.0
Potash feldspar...	70		
Soda feldspar.....	20	28.0	69.0
Potash feldspar...	80		
Soda feldspar.....	10	20.0	77.0
Potash feldspar...	90		
Potash feldspar...	100	11.5	85.0

RESULTS OF TESTS.

The order and rate of deformation of these potash feldspar-soda feldspar mixtures, as compared with similar properties of standard pyrometric cones Nos. 6, 7, 8, 9, and 10, are shown in figure 1. The percentage composition of the feldspar mixtures are shown at the top of the diagram, and the time interval and temperature increase as indicated by deformation of the standard cones are shown at the left.

DISCUSSION OF RESULTS.

The data in figure 1 are remarkably sharply defined as regards the end numbers of this series, but unfortunately the deformation ranges of the three softest members are so nearly the same that a number of checks must be made before the eutectic can be established.

From this preliminary test it seems that a mixture of approximately 69 per cent albite and 29 per cent microcline begins to deform at a lower

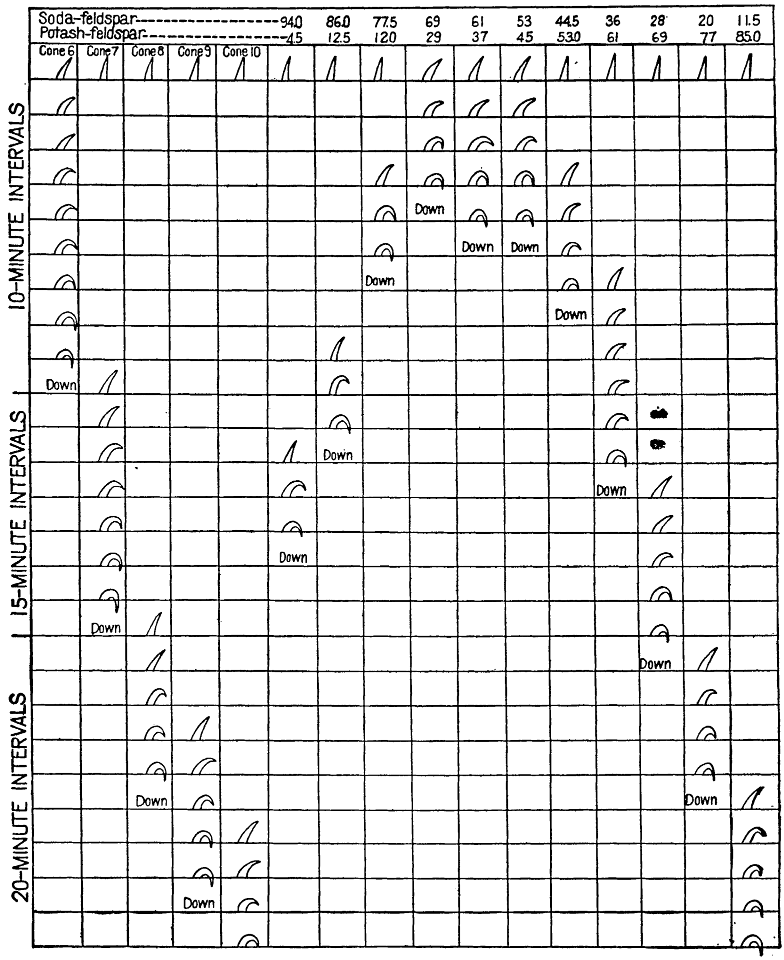


FIGURE 1.—Deformation of potash feldspar-soda feldspar cones.

temperature and completes the deformation process earlier than any other member of the series tested. The time required for the deformation of a cone made from this mixture was only half that required for a similar deformation of standard cone 6, the cone starting to deform at approximately the same time as cone 6 and being completely deformed when cone 6 had only half deformed.

Mixtures ranging from one that was 77.5 per cent albite and 21 per cent microcline to one that was 44.5 per cent albite and 53 per cent microcline completely deformed before cone 6 had completed deformation. The albite used in this study deformed at about the same rate as the eutectic mixture, but proved to be nearly one cone harder. The rate of deformation of the mixtures containing a higher percentage of microcline than the eutectic mixture decreases as the microcline content increases, the potash-feldspar end of the series having a time range of deformation equal to twice that of the albite.

Thus it is shown that a high soda content does not indicate a low deformation temperature. Also the approximate proportion of soda feldspar can not be determined except by a careful observation of the rate of deformation.

DEFORMATION TESTS OF FELDSPAR-QUARTZ MIXTURES.

One of the most confusing questions which confronts the user of feldspar is the extent to which the addition of quartz or free silica affects the pyrometric behavior of feldspar. In nature quartz is almost invariably associated with feldspar, and in most cases a complete separation of the two minerals would be very expensive if not impossible. Any feldspar purchased in the pulverized state is, therefore, very likely to contain a certain amount of free quartz unless special arrangement was made to have all quartz removed from the crude feldspar.

In order that a clearer understanding may be had of the effect of quartz on the different feldspars as regards deformation behavior, a study was made of potash feldspar-quartz mixtures and of soda feldspar-quartz mixtures.

The feldspars used were the same as those used in the potash feldspar-soda feldspar mixtures. These, as heretofore explained, are not pure minerals, but are as nearly pure as are obtainable in commercial quantities.

EXPERIMENTS WITH POTASH FELDSPAR-QUARTZ MIXTURES.

The composition of the potash feldspar and the quartz used was as follows:

Composition of potash feldspar and of quartz used.

[D. J. Demorest, analyst.]

Potash feldspar.		Quartz.	
	Per cent.		*Per cent.*
H_2O	0.50	Loss on ignition	0.11
SiO_2	64.30	SiO_2	99.18
Al_2O_3	19.64	Al_2O_3	.00
Fe_2O_3	0.08	Fe_2O_3	.26
TiO_2	Trace.	TiO_2	.01
CaO	Trace.	CaO	.01
MgO	Trace.	MgO	.01
BaO	.17		
K_2O	14.00		
Na_2O	1.32		
	100.01		99.58

The materials were ground to pass a 200-mesh screen and mixed in the proper proportions dry; the mixture was then made plastic by a small addition of dextrine solution. The various mixtures were molded into cones similar in shape and size to the standard pyrometric cones of commerce. The results of the tests are shown in figure 2. The proportions of feldspar and quartz in the various

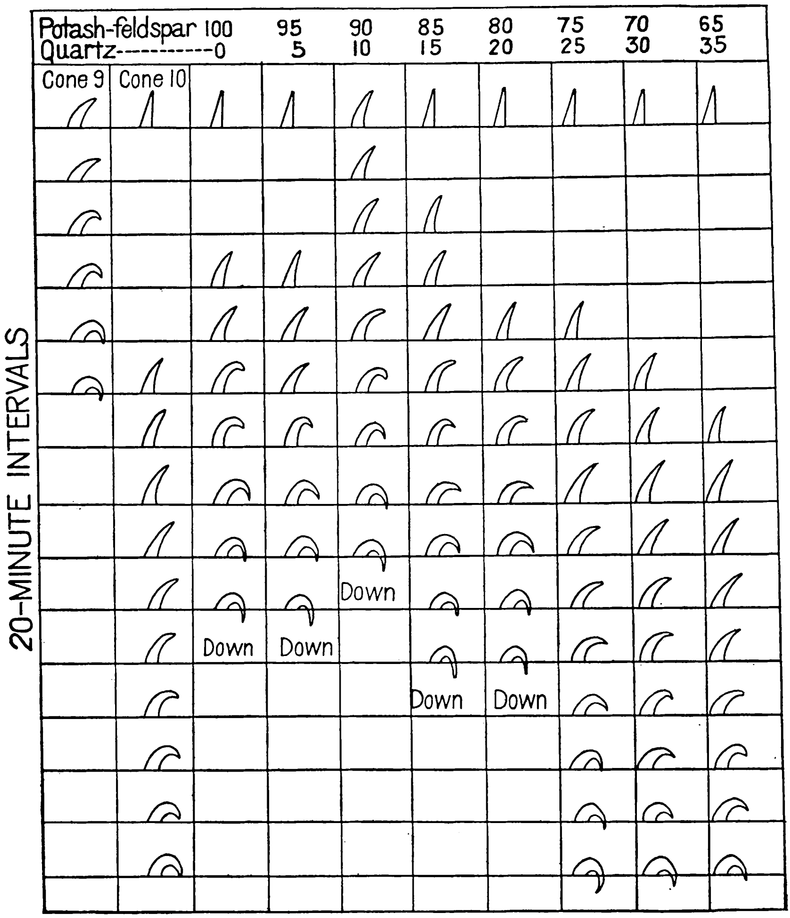


FIGURE 2.—Deformation of potash feldspar-quartz cones.

mixtures are recorded across the top of the diagram, and the intervals of time and of temperature as indicated by the deformation of the standard cones are shown along the left margin.

According to the results given in figure 2 the mixture of 90 per cent potash feldspar and 10 per cent quartz began to deform and completed deformation before any other mixture, and is therefore the deformation eutectic of this feldspar and quartz. The intervals between the deformation of this mixture and those of the mixtures containing about 5 per cent of quartz are so small that in practice the difference would hardly be noted unless carefully watched for. The pure feldspar deformed at the same temperature and rate as the mixture consisting of 95 per cent feldspar and 5 per cent quartz, and only when a mixture of 80 per cent feldspar and 20 per cent quartz was reached did any noticeable difference appear in the behavior of the cones. This mixture is slightly more refractory than the pure feldspar. The mixture consisting of 65 per cent feldspar and 35 per cent quartz is hardly more than one-half cone harder than the pure feldspar

CONCLUSIONS.

Feldspar high in potash and very low in soda content is only slightly affected by additions of quartz or flint. Substitution of quartz for feldspar in proportions up to 20 per cent may be made without materially affecting the temperature at which deformation begins or is completed. Substitution of quartz for feldspar up to 35 per cent may be made without affecting the deformation temperature more than one-half cone.

The foregoing indicates the futility of attempting to ascertain the extent to which a feldspar is adulterated with quartz by the deformation test alone.

DEFORMATION TESTS OF SODA FELDSPAR-QUARTZ MIXTURES.

A series of tests was also made with mixtures of soda feldspar and quartz. The soda feldspar and quartz used in the tests had the following composition:

Composition of soda feldspar and quartz used in tests.

[D. J. Demorest, analyst.]

Soda feldspar.		Quartz.	
	Per cent.		*Per cent.*
H_2O	0.20	Loss on ignition	0.11
SiO_2	68.18	SiO_2	99.18
Al_2O_3	20.12	Al_2O_3	.00
Fe_2O_3	.05	Fe_2O_3	.26
TiO_2	Trace.	TiO_2	.01
CaO	.85	CaO	.01
MgO	.05	MgO	.01
K_2O	.66		
Na_2O	9.38		
	99.49		99.58

These materials were ground to pass a 200-mesh sieve and mixed in the proper proportions in the dry state. A small amount of dextrine solution was then added to each mixture and they were molded into cones similar in size and shape to the standard pyrometric cones of commerce against which they were to be tested. The results of the test are shown in figure 3.

The percentages of soda feldspar and quartz in the various mixtures are recorded across the top of the diagram, and the time and the temperature intervals as indicated by the deformation of standard cones are shown on the left margin.

DISCUSSION OF RESULTS OF TESTS.

The above data indicates that additions of quartz do not affect soda feldspar in a manner similar to potash feldspar. None of the mixtures of soda feldspar and quartz, up to one containing 30 per cent of quartz, began to deform or completed deformation at a lower

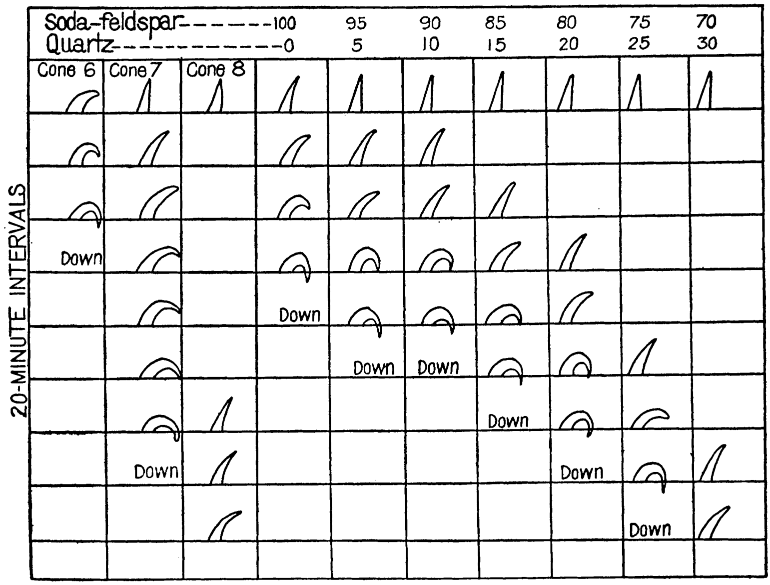


FIGURE 3.—Deformation of soda feldspar-quartz cones.

temperature than the pure soda feldspar. The mixture of 75 soda feldspar and 25 quartz, however, deformed more quickly after its deformation temperature was reached than did the pure soda feldspar. The rate of deformation, as indicated by the time intervals, is more rapid with soda feldspar and with all mixtures of soda feldspar and quartz than with potash feldspar or any mixture of potash feldspar and quartz. A rapid rate of deformation in soda feldspar-quartz mixtures may be a highly desirable feature in mixtures used for certain glazes, where fluidity is often desired, but in porcelain bodies it would be a detriment because the shorter the deformation range the greater would be the danger of warping.

DEFORMATION TESTS OF COMMERCIAL POTASH FELDSPAR-QUARTZ MIXTURES.

Another series of tests with mixtures of quartz and a feldspar which falls between the potash feldspar and the soda feldspar used in the investigations previously described, is of interest here as indicating the possible direction of the deformation curve of eutectic mixtures that lie between these two extremes. This feldspar contains 50 per cent more soda feldspar than the potash feldspar just described and is a good average of the feldspar offered for sale as potash feldspar. For convenience it is here referred to as commercial potash feldspar.

The analysis of this feldspar is given below. The quartz used was of the same composition as that used in the previous tests.

Composition of commercial potash feldspar.

	Per cent.
H_2O	0.17
SiO_2	65.37
Al_2O_3	17.92
Fe_2O_3	.02
TiO_2	Trace
CaO	.17
MgO	Trace
BaO	.15
K_2O	13.05
Na_2O	2.10
	98.95

The materials were ground and the mixtures prepared in the same manner as in the previous tests. The standard cones against which this series was tested included standard pyrometric cones 8 and 9, whereas the soda feldspar-quartz series was within the range of standard cones 6, 7, and 8, and the potash feldspar-quartz series was within the range of standard cones 9 and 10. Therefore this feldspar falls between the other two although a careful study of the results obtained reveals the fact that it more nearly approaches in behavior the regular potash feldspar than the soda feldspar. The results of the test are shown by the diagram in figure 4.

The figure shows that the increase in soda content causes the deformation eutectic almost to disappear and leaves only the rate of deformation to indicate that such an eutectic exists. The rates of deformation of the mixtures are somewhat faster than those of the pure potash feldspar-quartz mixtures but are much slower than those of the pure soda feldspar-quartz mixtures.

GENERAL CONCLUSIONS ON FELDSPAR-QUARTZ DEFORMATION TESTS.

From these deformation studies it appears that pure potash feldspar may be expected to deform at about cone 10 and that adding 10 per cent of quartz lowers the deformation temperature to a noticeable extent but does not increase the rate of deformation.

If a small proportion of the potash feldspar is replaced by soda feldspar (2 per cent Na_2O), the mixtures with quartz do not in any

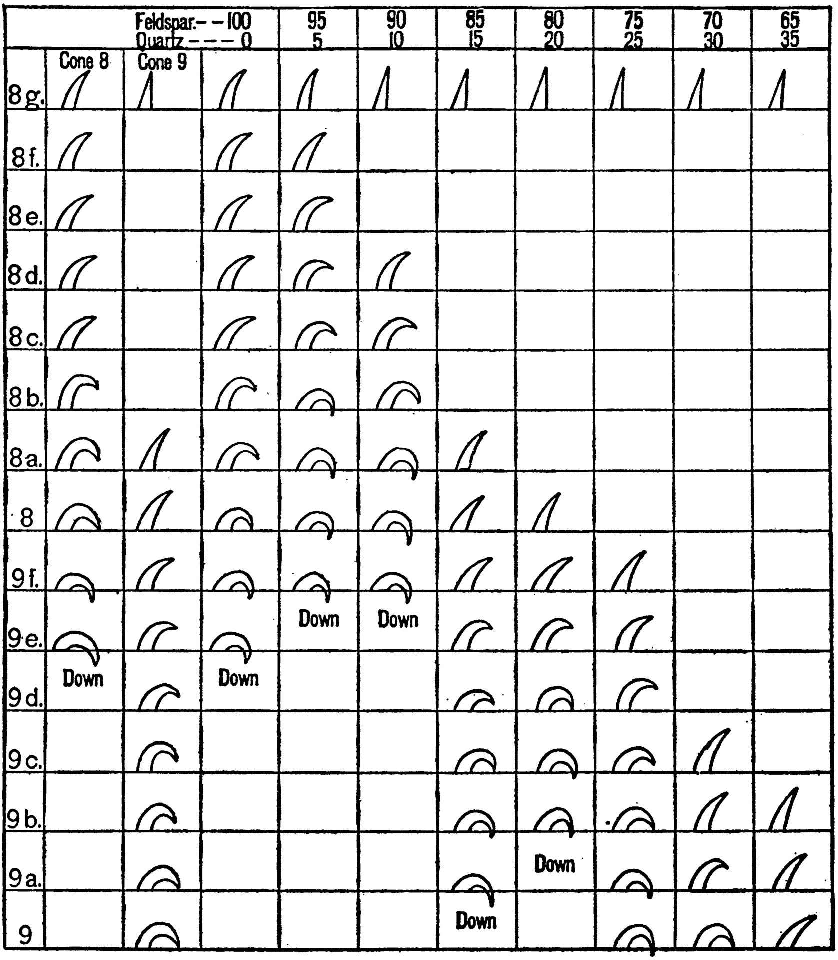


FIGURE 4.—Deformation of commercial feldspar-quartz cones.

case begin to deform at a lower temperature than the feldspar. However, a mixture of 95 per cent feldspar and 5 per cent quartz begins to deform at the same temperature as pure feldspar but completes deformation in slightly less time. A 90 to 10 mixture begins to deform at a noticeable interval after the pure feldspar and the 95 to 5 mixture, but completes deformation at the same time as the 95 to 5 mixture. Thus a 90 to 10 mixture has a greater rate of deformation than the potash-soda feldspar itself. All mixtures of this feldspar with quartz show a tendency to deform more rapidly after deformation begins than does the pure feldspar.

The soda feldspar-quartz mixtures show no evidence of having lower deformation temperatures than pure soda feldspar, and increasing the quartz content of the mixture increases with noteworthy regularity the temperature at which deformation begins. However, a mixture of 75 per cent soda feldspar and 25 per cent quartz deforms more rapidly after deformation begins, and in all mixtures of soda feldspar and quartz, and also pure soda feldspar, deformation proceeds much more rapidly after it begins than in potash or potash-soda feldspars or any of their mixtures with quartz.

CAUTION REGARDING INTERPRETATION OF THE ABOVE DATA.

The above data must not be interpreted as indicating that commercial feldspars containing quartz are equal in value to pure feldspars. Any adulteration with quartz means that a larger amount of the feldspar-quartz mixture must be used in order to furnish the necessary quantity of feldspar for fluxing. On the other hand, the percentage of quartz which is added to the body as ground flint must be reduced by the amount of quartz added with the feldspar. For example, a body having the composition 20 per cent feldspar, 35 per cent flint, and 45 per cent clay is to be made, using a commercial feldspar which contains 80 per cent feldspar and 20 per cent quartz. In order to introduce the proper amount of pure feldspar, 20 per cent, 25 per cent of commercial feldspar (20 parts feldspar plus 5 parts quartz) must be used. The 5 per cent of quartz added with the feldspar must be deducted from the 35 per cent of flint, leaving 30 per cent of flint to be added as such. The actual working recipe of the above body would be 25 per cent commercial feldspar, 30 per cent flint, 45 per cent clay.

This shows that the adulteration of feldspar by quartz does not in any way make the feldspar more active in the pottery mixtures unless the mixture contains no flint.

DEFORMATION TESTS OF FELDSPAR-BERYL MIXTURES.

The results of tests of feldspar-beryl mixtures and of feldspar-muscovite mixtures, which have already been published in Bulletin 53 [a] of the bureau, are described in the following:

The presence of crystals of beryl in the pegmatite dikes, and the fact that they are found chiefly associated with the parts richest in feldspar, made it necessary to ascertain what effect this mineral exerts on the industrial value of feldspar.

[a] Watts, A. S., Mining and treatment of feldspar and kaolin in the southern Appalachian region: Bull. 53, Bureau of Mines, 1913, pp. 28-30.

For this purpose, a series of mixtures of microcline and beryl was prepared from the two minerals ground separately to 200-mesh fineness, and made into cones. These cones were tested in the same manner as were the feldspar-quartz and feldspar-muscovite mixtures, and the results are shown in figure 6.

Beryl has the following composition, $3BaOAl_2O_3.6SiO_2.\frac{1}{2}H_2O$.

The mixture containing 20 per cent beryl begins to deform as cone 6 touches the plate. The mixtures containing 15 per cent, 10 per cent, and 5 per cent beryl follow quickly after the mixture containing 20 per cent beryl. The feldspar-beryl series continue to deform in the order in which they start, the first to begin deforming being the first to touch the plate. The entire series deforms completely within less than one-cone temperature range, starting at cone 6, touching and extending to cone 7, not quite touching the plate. This series indicates that the deformation temperature decreases with increase of beryl content, at least to 20 per cent, where the series ended. As a test cone of pure beryl was tested with this series and was heated up to cone 8 without deforming, a eutectic is indicated between feldspar and beryl. A study of the

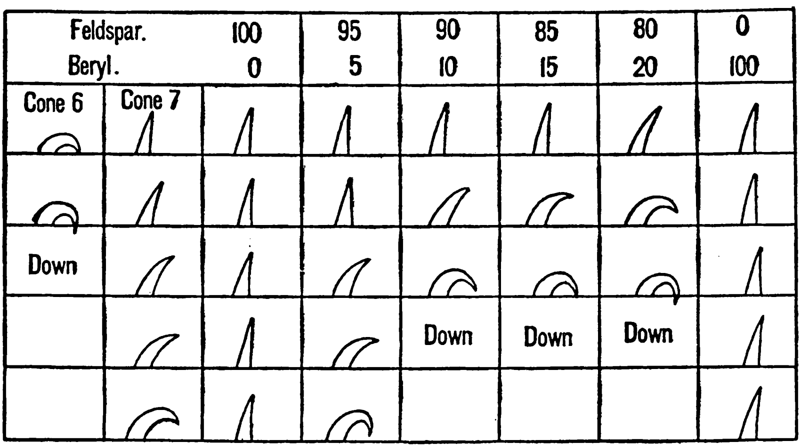


FIGURE 5.—Deformation of feldspar-beryl cones.

fired cones indicates slightly more deformation in the mixture containing 15 per cent beryl, but as this was not apparent in the process of deformation, its influence is difficult to determine.

DEFORMATION TESTS OF FELDSPAR-MUSCOVITE MIXTURES.

As muscovite (white mica) is present in nearly every pegmatite in the district investigated, it is important to know what effect it exerts on the deformation point and color of the feldspar. For this purpose a series of feldspar-muscovite mixtures was made and tested in the same manner as the feldspar-quartz mixtures. The muscovite and the feldspar were both ground to pass a 200-mesh sieve. The results of this test are shown in figure 6. These results are especially interesting in view of the fact that muscovite has the composition $K_2O.3Al_2O_3.6SiO_2$, and contains the same elements as feldspar, but by virtue of its higher alumina content is more difficultly fusible, being reported by Rieke [a] as deforming with cone 13.

In the figure it will be noted that the mixture containing 5 per cent of muscovite begins to deform before any other mixture tested. The order in which the various mixtures deform is regular, the mixture containing 20 per cent muscovite being the last to begin to deform. The rate of deformation, however, appears to be just the reverse

[a] Rieke, R., Sprechsaal, Bd. 42, 1908, p. 578.

of this, as the mixture containing 20 per cent muscovite deforms until it touches the plate before any other of the series. Note also that as the mixture containing 5 per cent muscovite, which has the slowest rate of deformation, touches the plate the pure feldspar shows the first indication of deformation. Thus it appears that additions of finely ground muscovite to a microcline feldspar lowers the deformation temperature, and the rate of deformation increases with the increase in muscovite.

The influence of muscovite upon the color of the feldspar is really the most important consideration in the presence of muscovite, although the proportions present in any deposit known would hardly average 1 per cent. A specimen containing this percentage is scarcely distinguishable from pure feldspar. The tint produced by the

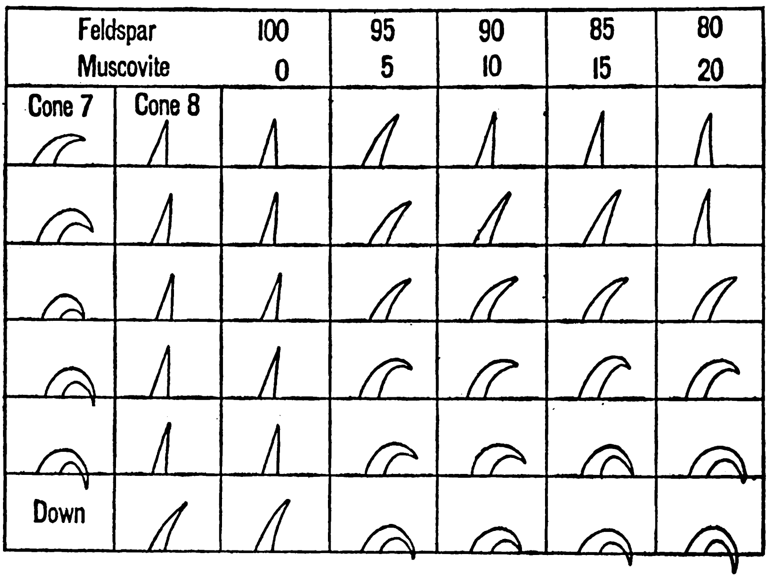


FIGURE 6.—Deformation of feldspar-muscovite cones.

muscovite is a pale drab, which is the same as is imparted in porcelains by the ball clay, and hence would not be noticed.

DEFORMATION TESTS OF FELDSPAR-BIOTITE MIXTURES.

As biotite (black mica) is a constituent of practically every pegmatite dike and is considered by users of feldspar as an injurious, if not the most injurious, associate mineral, it is important to know the effect of biotite on the pyrometric properties of feldspar.

Biotite has the composition $K_2O.4MgO.2Al_2O_3.6SiO_2$, in which MgO may be replaced in part by FeO and Al_2O_3 by Fe_2O_3, the depth of color being determined by the extent of this replacement.

A series of feldspar and biotite mixtures was prepared by pulverizing each of the minerals until it passed a 200-mesh bronze sieve, mixing them in the proper proportions, and regrinding each mixture carefully to insure as intimate a mixture as possible. The mixtures were made into cones of standard dimensions and these were tested against standard pyrometric cones for deformation temperature and rate of deformation. The results of the tests are shown in figure 7.

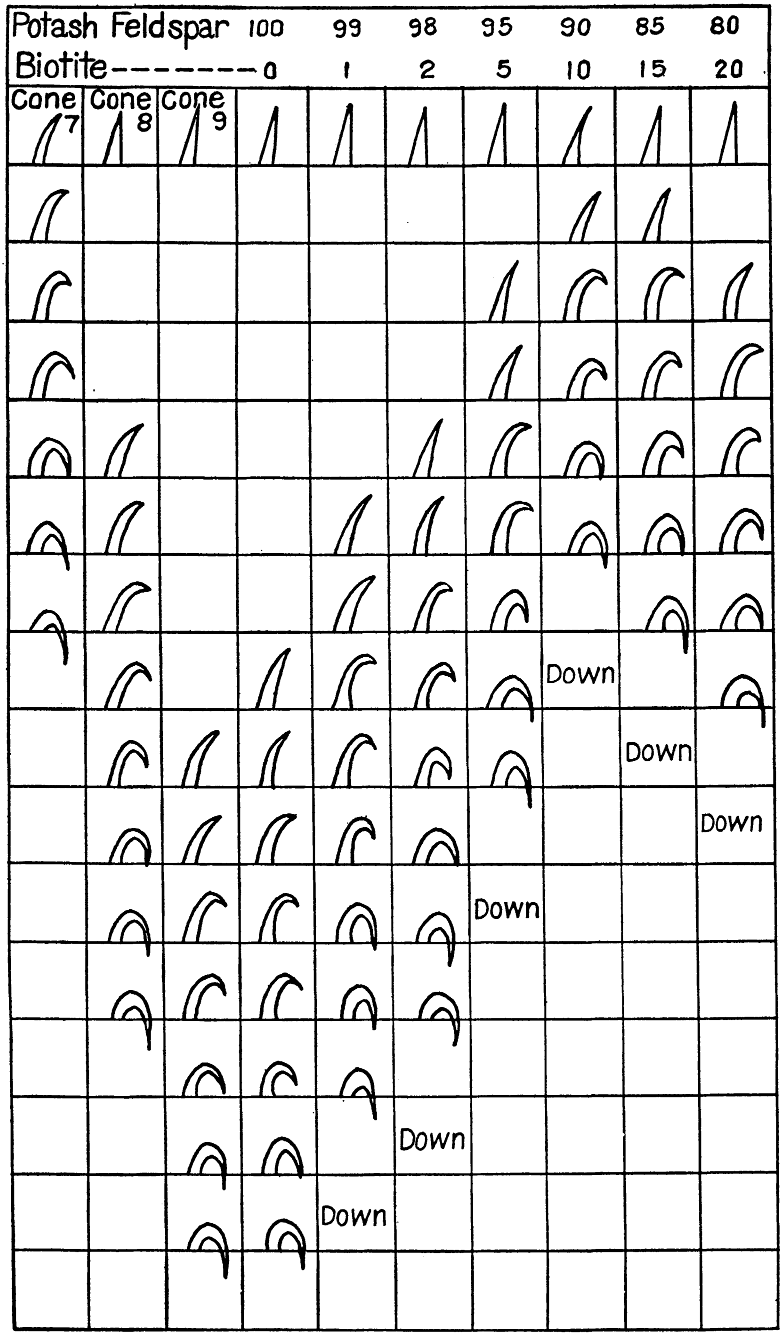


FIGURE 7.—Deformation of feldspar-biotite cones.

The results indicate that a eutectic mixture is formed with about 90 per cent feldspar and 10 per cent biotite. The feldspar alone deformed at about cone 9, whereas the eutectic mixture deformed at about cone 7, indicating that biotite causes a pronounced lowering of the deformation temperature. The rate of deformation is not noticeably affected. The coloring action of the biotite is a complete barrier to the use of biotite-bearing feldspar in most ceramic industries, as 1 per cent of biotite colors the fired feldspar a pronounced gray and 2 per cent produces a dark gray-brown color. The mixtures containing 5 per cent biotite show a tendency to boil when deformation begins, a characteristic of mixtures containing an excess of magnesium.

EFFECT OF KAOLIN ON PROPERTIES OF COMMERCIAL FELDSPAR.

The presence of kaolin and kaolinized material in commercial feldspar makes a knowledge of the effect of kaolin on the properties of the feldspar important. Such an investigation has been made by Hewitt Wilson, ceramic engineer, in preparing data for a thesis at Ohio State University, and those parts of the paper [a] which bear on this subject are given here.

DEFORMATION TESTS OF FELDSPAR-KAOLIN MIXTURES.

KAOLINIZATION OF FELDSPAR AND SIGNIFICANCE.

The kaolin impurity in most commercial feldspars averages from 1 to 3 per cent and usually is the result of the decomposition of more exposed portions of the bed. A description of this "decomposition of feldspar and the recombination of a portion of the decomposition products of kaolin" has been given by Watts.[b] Briefly it is this:

The molecular formula for orthoclase or microcline feldspar is $K_2O.1Al_2O_3.6SiO_2$. By water solution the K_2O is lost, leaving $Al_2O_3.6SiO_2$ as the insoluble decomposition products. The Al_2O_3 and $2SiO_2$ of this recombine with the absorption of $2H_2O$ to form kaolin, leaving 4 molecules of silica as free quartz. Thus the presence of kaolin and quartz impurities in a bed of feldspar is partly accounted for.

The increase of the combined water and the decrease of the potash content are thus indicators of the degree of kaolinization. As the water content increases, the deformation temperature also increases. By plotting the water alkali curve alongside this other, a corresponding deformation temperature can be obtained for each percentage of alkali in the feldspar. We, therefore, may say that generally the more kaolinized is the feldspar—that is, the higher the water and lower the alkali content—the higher will be the deformation temperature. However, when the feldspar contains less than 16 per cent kaolin, it has been found that there are indications of the formation of a eutectic, so that the rise of the deformation temperature is not as rapid as with higher percentages of kaolin.

Simonis (Sprechsaal, 1907, vol. 2) gives a deformation temperature determination for Zettlitz kaolin-feldspar mixtures and it was decided to check this curve with our kaolin and feldspar.

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[a] Wilson, Hewitt, Deformation study of feldspar-kaolin mixtures: Trans. Am. Cer. Soc., vol. 15, 1913, pp. 217-232.

[b] Watts, A. S., Mining and treatment of feldspar and kaolin in the southern Appalachian region: Bull. 53, Bureau of Mines, 1913, p. 16.

Watts [a] found that there was an apparent eutectic with 90 per cent feldspar and 10 per cent quartz. As most commercial feldspars contain both quartz and kaolin impurities it would be nearer actual working conditions to have both present in this study, after the mixture of feldspar with quartz and with kaolin had been investigated separately.

METHOD AND PROCEDURE.

The chemical analysis of the feldspar and also of the theoretical microcline are as follows:

		Feldspar used.	Theoretical microcline.
Moisture	per cent	0.17	.....
SiO_2	do	65.37	64.75
Al_2O_3	do	17.92	18.34
TiO_2	do	Trace.	.....
Fe_2O_3	do	.02	.....
CaO	do	.17	.....
MgO	do	Trace.	.....
K_2O	do	13.05	16.90
Na_2O	do	2.10	.....
		98.80	99.99
Specific gravity		2.57	2.56

The purest kaolin obtainable was used.

		Kaolin No. 83.	Theoretical kaolin.
Moisture	per cent	13.22	13.90
SiO_2	do	46.67	46.30
Al_2O_3	do	39.07	39.80
Fe_2O_3	do	.11	......
TiO_2	do	.02	......
CaO	do	Trace.	......
MgO	do	Trace.	......
Na_2O	do	.11	......
K_2O	do	.25	......
		99.45	100.00

The crude, unwashed clay was blunged in a small household churn, passed through a 200-mesh screen to remove all the larger quartz and mica particles, and then sized in a Schultz elutriation apparatus * * *.

Four sizes of grain were separated, dried, and their average size determined with a microscope:

Jar No. 1=0.0032 to 0.0040 inches.
Jar No. 2=0.0024 to 0.0032 inches.
Jar No. 3=0.0016 to 0.0024 inches.
Jar No. 4=0.0009 to 0.0016 inches.

Most of the clay grains were taken from jar No. 3, and after the relative size of grain study this size was used altogether for all the cones.

The feldspar and kaolin ingredients of the cone mixtures were weighed out * * * and the two were mixed dry by passing twice through a 150-mesh screen and enough dextrine added to permit its being formed * * * into a standard size cone * * *. Each cone was stamped with its serial and clay content number and baked in a constant temperature oven at 109° C.

From 24 to 27 hours were used in reaching cone 8; rapid firing maintained until cone 6 to 7 was reached and then several hours intervening until cone 8 should start.

[a] Watts, A. S., Op. cit., pp. 26, 27, 28.

DATA AND RESULTS.

To determine the effect of size of grain of the kaolin, a series was made up of 0.2, 5, 7.5, and 10 per cent of each of the sizes Nos. 2, 3, and 4 of kaolin and fired as a preliminary burn. No difference could be distinguished between the three, and so kaolin No. 3 was used throughout the rest of the determination.

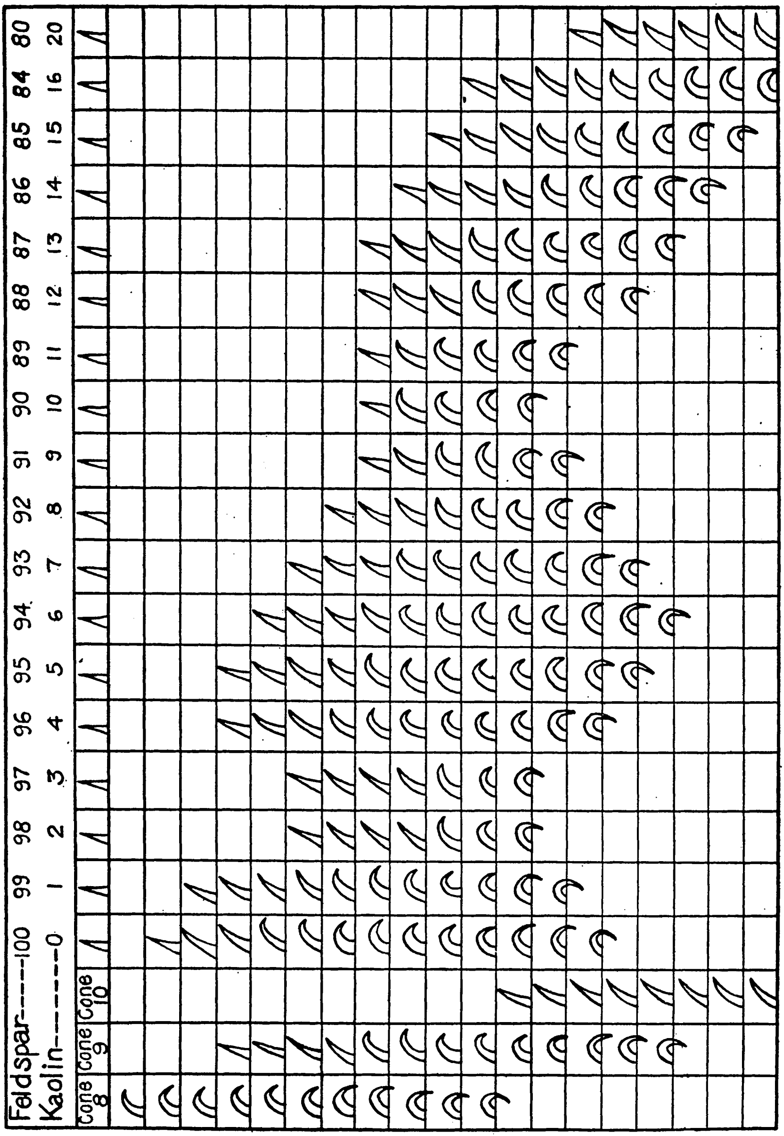

FIGURE 8.—Deformation of kaolin-feldspar cones.

Kaolin was added to feldspar in 1 per cent intervals, from 0 to 16 per cent. Beyond this the kaolin percentages were 25, 30, 35, 40, and 45. The average of 9 burns is given in figure 8.

This chart indicates that—

1. The pure feldspar deforms between cone 8 and cone 9, being closer to the latter.
2. Around 2 and 3 per cent kaolin the start of deformation is late, the rate is fast, and the end is before that of pure feldspar.
3. At 5 and 6 per cent the rate decreases until it is about that of the pure feldspar, but the start and end of deformation is behind that of the latter.
4. In the 9 to 11 per cent region there is another slow starting, a rapid rate, and quick finish to deformation. The rate here is faster than any other.
5. Beyond 10 per cent kaolin, normal conditions are gradually resumed, the start and finish progressing toward higher temperatures with the increase of kaolin.

Cones in which the kaolin impurity varies only by 1 per cent do not show much difference in their deformation. Hence regions, instead of definite percentages, must be used in terming these indicated eutectics.

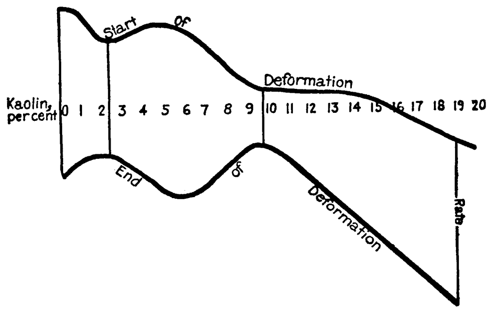

FIGURE 9.—Diagram showing relation of rate of deformation to proportion of kaolin. Vertical distance between lines represents rate of deformation of pure feldspar.

Figure 9 shows in a more general way the rate of deformation, that being designated by vertical distances between the two curves. The normal rate—that is, that of pure feldspar—is represented by the vertical distance between the two dotted lines dropping to the right as the kaolin content increases.

CONCLUSIONS.

The results of these two charts show that there are two indicated deformation eutectics, the lesser in the region of 2 to 3 per cent kaolin and 98 to 97 per cent feldspar, and the greater at 9 to 11 per cent kaolin and 91 to 88 per cent feldspar. Correspondingly, 5 to 6 per cent kaolin and 95 to 94 per cent feldspar is a region which may be termed a deformation compound. When we speak of regions, it is meant that in the limits given there is a definite percentage at the maximum or minimum point which should be termed the deformation eutectic, or compound, but that it has not been accurately determined.

REFIRING.

A final determination was made to this phase of the study by grinding up the deformed cones to pass 150 mesh, mixing with dextrine, reforming into cones and firing again; 0, 2, 4, 6, 7, 5, 10, 12.5 per cent of kaolin were used. The results as given in figure 10 in general check the above results, the deformation, however, taking place from two to three cones lower—close to cone 6. Pure feldspar started about the same time as the others, but was slow in deforming. Two, 4, 7.5, and 10 per cent were practically the same and deformed more rapidly than pure feldspar. Six per cent kaolin was slightly behind 2 and 10 per cent and dropped more like 0 per cent, thus indicating the higher region of 4 to 6 per cent.

KAOLIN-FELDSPAR-QUARTZ TESTS.

Kaolin was added to a 1 to 9 mixture of quartz-feldspar in the percentages 0, 2, 4, 6, 8, and 10. The results of two burns are given in figure 11. The deformation

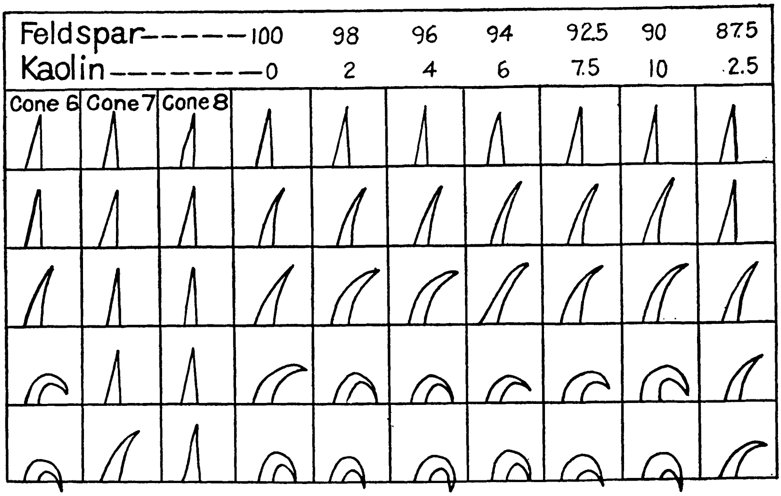

FIGURE 10.—Deformation of refined kaolin-feldspar cones.

took place with cones 8 and 9, the same as with kaolin and feldspar alone. With 8 per cent kaolin went the most rapid deformation, 10 per cent and 0 per cent kaolin

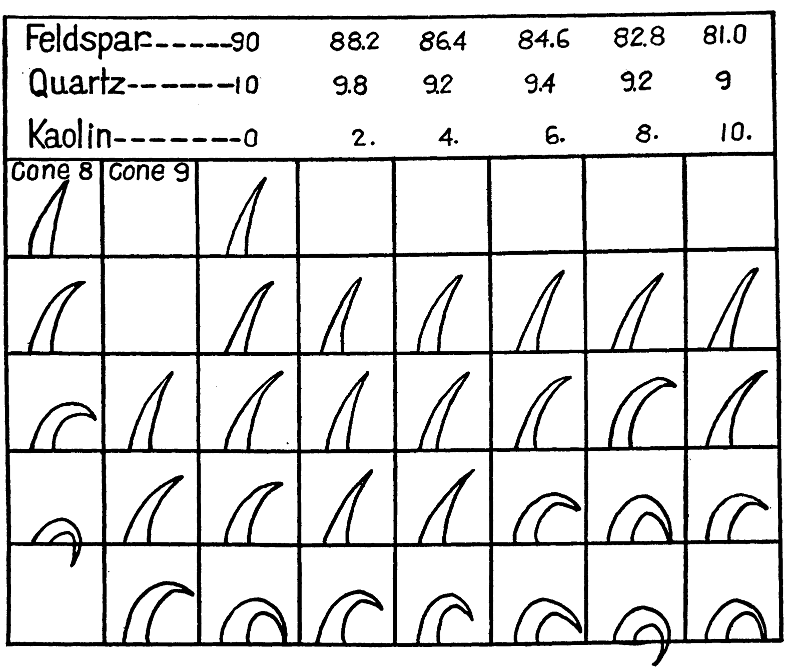

FIGURE 11.—Deformation of kaolin-feldspar-quartz cones.

came next, with a lesser rate, leaving 2 to 4 per cent as the "high" region and the slowest to deform.

Hence, in a general way, the feldspars with both quartz and kaolin impurities may be made to deform with and before pure feldspar, especially when in the region of 8 to 10 per cent kaolin, 9.2 to 9 quartz, and 82.8 to 81 per cent feldspar.

MIXTURES HIGH IN KAOLIN.

Dr. Simonis (Sprechsaal, 1907, vol. 2) gives the following table for the deformation of kaolin-feldspar mixtures:

Deformation points of kaolin-feldspar mixtures.

No. of mixture.	Proportions in mixture.		Deformation point, cone—
	Zettlitz kaolin.	Feldspar.	
	Per cent.	*Per cent.*	
67	15	85	9
74	30	70	14
80	45	55	26+
85	55	45	28
89	70	30	31+
92	85	15	33 to 34

As is shown by figure 12, we partly checked this with our kaolin and feldspar, the slight variations being probably due as much to furnace irregularities as to anything else. Standard sized cones were made of the different mixtures and tested with standard cones in a small gas-fired muffle furnace.

In the figure the dotted lines show where our results disagree with those of Simonis. Notice the rise in deformation of 12 cones between the limits of 30 to 40 per cent kaolin.

GRAPHIC GRANITES AS A SOURCE OF FELDSPAR.

As the exposed deposits of pure feldspar in the United States are rapidly being worked out and the locating of new deposits of pure material is a matter of more or less uncertainty, it seems wise to seriously consider the available sources of feldspar which is not pure but contains no impurity that would make the feldspar unfit for ceramic uses. The most fruitful source of such investigation is the graphic granites or graphic pegmatites. The pure feldspar has been obtained from isolated lenses in these pegmatite dikes, and in mining it vast quantities of pegmatite rich in feldspar and containing little or no impurity, except quartz, were quarried. This was rejected as waste. When the lenses of pure material were becoming exhausted, the operator began to work over these waste heaps and also to quarry the walls adjoining the pure feldspar lenses, and he found there much material free from other impurity except quartz. This material was sorted, and the portion in which the quartz content did not exceed 10 or 15 per cent was accepted and mixed with the pure feldspar. No serious difficulty resulted from the replacement of 5 or 10 per cent of the feldspar by quartz, as this amount of variation in the ordinary pottery body might often occur through the use of material in which an excess of moisture existed.

However, each year the supply of available pure feldspar becomes less, and also the part of the graphic granites which is richest in feldspar is being used up, leaving a poorer assortment from which to select.

Owing to the gradual hardening of the commercial grade of New England feldspars, which is not due to any change in the feldspar

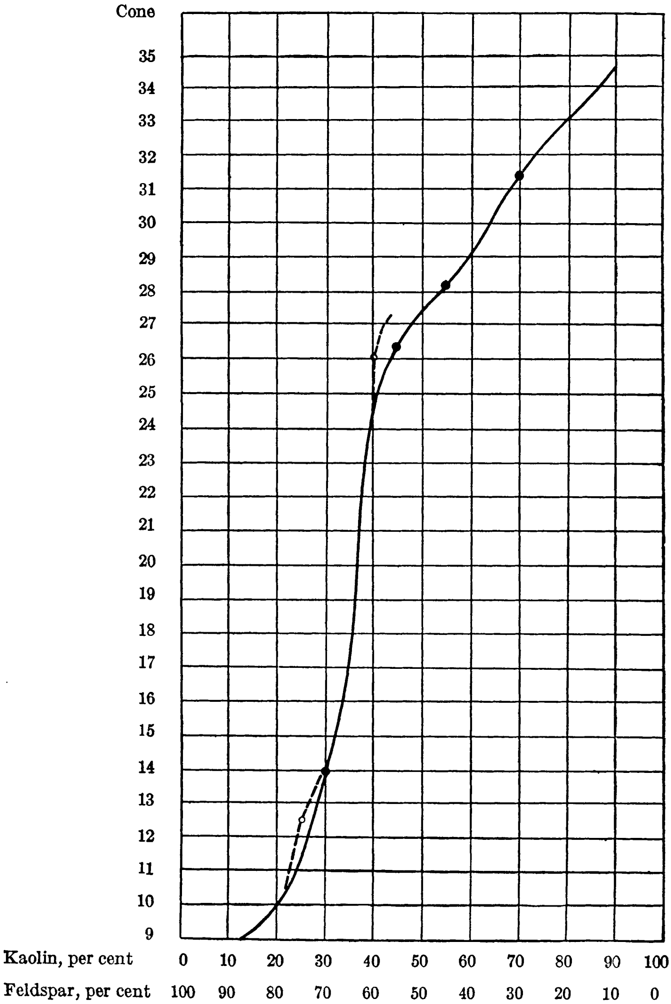

FIGURE 12.—Deformation curve of kaolin-feldspar series. After Simonis. Dotted lines show where results of Wilson's tests disagree with those of Simonis.

itself, but merely to the increased quartz content, many users have turned to other sources of supply, thus fortunately leaving the New England feldspars to those manufacturers who found their use essential to proper color in their wares. This is especially true of the Maine feldspars, which are recognized as being superior in color to any other American feldspar except the North Carolina feldspars, the cost of which is prohibitive in many industries.

PROPERTIES OF GRAPHIC GRANITES.

Graphic pegmatites, or graphic granites as they are generally termed, do not differ in essential constituents from ordinary pegmatite, except that the associate quartz is distinctly crystalline, as is shown in Plate I, *B*. The remarkable similarity of the quartz crystals to Chinese lettering has led to the application of the term "graphic granite" or "Schriftgranit," as it is called in German literature.

The value of the graphic granites for ceramic purposes naturally depends on the amount of impurity present and it is worthy of note that when the feldspar and quartz are intercrystallized as in this graphic form the amount of other minerals present is much less than in other forms of pegmatite or granite. As quartz is the chief associate mineral, its effect on the deformation point of the feldspar is of importance to the ceramist.

FELDSPAR-QUARTZ RATIO IN GRAPHIC GRANITES.

Vogt[a] has offered the theory that in graphic granite the quartz and feldspar are present in eutectic proportions. He presents as evidence the following analyses of graphic granites and their recalculation into feldspar and free quartz contents.

Composition of graphic granites.

	No. 1.	No. 2.	No. 3.	No. 4.
Composition:	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
SiO_2	74.04	74.00	73.82	74.47
Al_2O_3	14.44	14.31	14.44	15.13
CaO	.33	.39	.35	.72
K_2O	9.36	9.02	8.90	7.06
Na_2O	2.01	2.42	2.45	2.01
Feldspar	74.7	75.3	75.3	72.7
Free quartz	25.3	24.7	24.7	27.3

In conclusion he says:

> When the potash feldspar is in excess, the proportions of feldspar and quartz in graphic granites are absolutely constant or only very slight variable * * * From this we conclude with absolute certainty that the graphic granite is a eutectic mixture and has a composition approaching 74 per cent feldspar and 26 per cent quartz.

Teall[b] concludes that the graphic granite represents the eutectic between feldspar and quartz.

Johnson[c] concludes that the feldspar-quartz content in graphic granites has a definite ratio, dependent upon the type of feldspar present. When the feldspar is orthoclase the molecular ratio of feldspar to quartz is 2:3. When the feldspar present is plagioclase the molecular ratio is 1:2. When the feldspar present is albite the molecular ratio is 1:3.

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[a] Vogt, J. H. L., Die Silikatschmelz-lösungen, 1904, pp. 117–128.
[b] Teall, J. J. H., British petrography, 1888, p. 402.
[c] Johnson, H. E., Geologiska föreningens Förhandlinger, Bd. 27, 1905, p. 119.

Bygden[a] concluded from a study of many analyses that the type of feldspar present bears no definite relation to the feldspar-quartz ratio. He believes that a definite feldspar-quartz ratio does exist in most graphic granites, but thinks it is not so simple as Vogt and Johnson imagine.

Bastin,[b] after considering the data and opinions of other investigators, compiled a table of mineral compositions of graphic granite in which he included not only all available foreign data but also the compositions of three Maine graphic granites. From a study of these he finds that even among graphic granites whose feldspars are almost identical in composition, there are considerable variations in the feldspar-quartz ratio. Bastin's table of graphic granite compositions is included as analyses D to G in the table following.

VARIATION IN GRANITES THROUGHOUT A GIVEN DISTRICT.

The subject of chief interest to users of feldspar is the possible variation of graphic granites throughout a given district, both as regards ratio of feldspar to quartz and also as regards the chemical composition and physical behavior of the feldspar component of the graphic granites.

In the following table samples A, B, and C were collected by A. S. Watts, of the Bureau of Mines, and were analyzed by A. C. Fieldner of the bureau. Samples D to G were collected by the United States Geological Survey and were analyzed by George Steiger in the laboratory of the Geological Survey.

Composition of New England graphic granites.

CHEMICAL COMPOSITION.

	A.[c]	B.[c]	C.[c]	D.[d]	E.[d]	F.[d]	G.[d]
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
SiO_2	73.89	74.34	74.53	73.89	73.92	72.76	71.00
Al_2O_3	14.33	14.45	14.26	13.75	14.26	15.47	16.31
CaO	Trace.	Trace.	Trace.	None.	None.	.19	.22
MgO	do	do	do	do	do	None.	None.
BaO	None.	None.	None.				
Fe_2O_3	.16	.14	.16	.26	.30	(e)	(e)
K_2O	9.02	8.63	8.55	9.00	8.99	9.28	8.66
Na_2O	2.14	2.00	2.25	2.10	2.06	2.35	3.44
H_2O	.33	Trace.	.30	.24	.11	.15	.12

CALCULATED MINERAL COMPOSITION.

	A.	B.	C.	D.	E.	F.	G.
Potash feldspar	53.4	51.1	50.6	54.4	55.2	55.0	51.4
Soda feldspar	18.2	16.9	19.1	18.5	18.5	20.0	29.1
Lime feldspar						1.0	1.0
Free quartz	26.9	29.7	28.7	27.1	26.3	23.0	17.6
Other constituents	1.5	2.3	1.6	Trace.	Trace.	1.0	.9
	100.0	100.0	100.0	100.0	100.0	100.0	100.0

[a] Bygden, A., Über das quantitative Verhältniss zwischen Feldspat und Quarz in Schriftgraniten: Bull. Geol. Inst. Univ. Upsala, vol. 7, 1904, pp. 1–18.
[b] Bastin, E. S., Geology of the pegmatites and associated rocks of Maine, including quartz, feldspar, mica, and gem deposits: U. S. Geol. Survey Bull. 445, 1911, pp. 39–42, 124–125.
[c] Bureau of Mines samples.
[d] Geological Survey samples.
[e] Fe_2O_3 included with Al_2O_3.

Sample A.—Fine-grained graphic granite (see Pl. I, *B*) from newly opened quarry of Maine Feldspar Co., east slope of Mount Ararat, Topsham, Maine.

Sample B.—Medium-grained graphic granite (see Pl. I, *B*) from Wm. Willis quarry, Cathance, Maine.

Sample C.—Coarse-grained graphic granite (see Pl. I, *B*) from Golding Sons Co. quarry, Georgetown Peninsula, Maine.

Sample D.—Coarse graphic granite, Fisher's quarry, Topsham, Maine. Quartz layers about 1 inch across and feldspar layers about 4 inches across.

Sample E.—Moderately coarse graphic granite, Fisher's quarry, Topsham, Maine. Quartz layers about 0.05 inch across and feldspar layers about 0.15 inch across.

Sample F.—Fine grained graphic granite from Kinkle's feldspar quarry, Bedford, West Chester Co., N. Y. Quartz layers about 0.03 inch across and feldspar layers about 0.08 inch across.

Sample G.—Graphic granite from Andrews quarry, Portland, Conn. Quartz layers vary but average not more than 0.02 inch across. The feldspar layers average nor more than 0.05 inch across. Some areas of pure feldspar in the sample increase the the feldspar content shown by the analysis above what a graphic granite of this fineness should yield.

Study of the analyses A, B, C, D, and E, all of which are from the chief feldspar-producing district of Maine, shows no greater difference in chemical composition than would be expected in samples taken from different places in a single quarry. The maximum variation in potash content is 0.47 per cent, in soda 0.25, in total alkali only 0.53, in alumina 0.70, and in silica 0.64 per cent. The calculated mineral compositions indicates that the maximum variation in free silica content is only 3.4 per cent.

From the foregoing it appears that the statement of Vogt regarding the ratio of feldspar and quartz seems to hold for Maine graphic granites. A comparison of the calculated mineral compositions indicates that there is no relation between the variation in free quartz content and the size of quartz particles.

RELATION BETWEEN PYROMETRIC BEHAVIOR AND FELDSPAR CONSTITUENTS.

The next problem was to determine the relation between the pyrometric behavior of the graphic granites and of their feldspar constituents. For this study, three graphic granites, A, B, and C, were selected which grade from a very fine to a very coarse grained granite. The quartz in all three samples was of the smoky variety and the feldspars are indicated by optical analyses to be microclines with small intergrowths of albite.

PREPARATION OF SAMPLES.

The three samples were photographed (Pl. I, *B*) and then each sample was divided into two equal parts; one part was pulverized as pegmatite and the other part carefully cleaned of all free quartz and pulverized as pure feldspar. In each case the pulverized material was ground dry to pass a 200-mesh sieve, mixed with a small amount of dextrine, and molded in the plastic state into cones similar to standard pyrometric cones. These cones were tested as follows: (*a*) For the deformation temperatures and rates of deformation of the graphic granites as such; (*b*) for the deformation temperatures and rates of deformation of the pure feldspar components; (*c*) for the relation between the graphic granites and mixtures of their feldspar components and known proportions of pulverized quartz. The quartz used in this last test was quartz sand pulverized dry to pass a 200-mesh sieve.

RESULTS OF TESTS.

The relative pyrometric behavior of the graphic granites and their feldspar components is shown in figure 13.

The diagram shows that at least in the case of these graphic granites of Maine the deformation temperature lies well beyond that

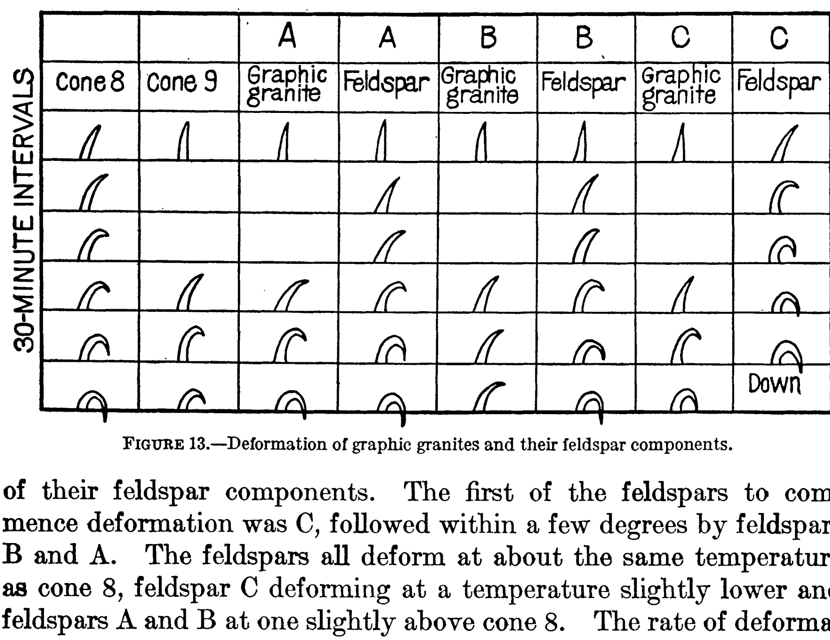

FIGURE 13.—Deformation of graphic granites and their feldspar components.

of their feldspar components. The first of the feldspars to commence deformation was C, followed within a few degrees by feldspars B and A. The feldspars all deform at about the same temperature as cone 8, feldspar C deforming at a temperature slightly lower and feldspars A and B at one slightly above cone 8. The rate of deformation of the three feldspars varies slightly, that of feldspar C, which begins to deform first, being the highest. Feldspars A and B both deform at the same rate as cone 8.

The three graphic granites of which these three feldspars formed a part do not deform until cone 9, and furthermore do not deform in the same order as the feldspars, but follow the order of the calculated free quartz content. Graphic granite A, which has a calculated free quartz content of 25.8 per cent, begins to deform noticeably ahead of the other two granites and completes deformation distinctly ahead of them. Graphic granites B and C, carrying respectively 27.6 per cent and 27.4 per cent of free quartz, begin to deform at the same temperature, but C deforms more quickly than B and is completely deformed when B is not more than half deformed.

The results of the analyses show that graphic granite C has the lowest alumina content and the highest soda content, both of which factors tend to favor rapid deformation in the pure feldspar. However, the small excess of free quartz in this granite more than counteracts the effect of the more fusible feldspar and causes the granite to deform at a higher temperature than graphic granite A, which contains slightly less soda and slightly more alumina but contains 1.6 per cent less free quartz.

Graphic granite B, which is the richest in free quartz and contains the highest percentage of alumina and the lowest percentage of soda, is the most refractory of the three samples, and its feldspar component is more refractory than that contained in either of the other two graphic granites.

Thus it is clear that a slight variation in composition may greatly change the temperature and rate of deformation of a graphic granite.

It must be remembered, however, that the three graphic granites tested are so similar that in a commercial plant the difference in pyrometric behavior would hardly be noticed.

The main point brought out by this experiment is the fact that graphic granites high in potash and low in soda and containing no lime, of which the graphic granites of Maine are examples, deform at temperatures distinctly higher than do their feldspar components. Hence they are not deformation eutectic mixtures of feldspar and quartz. Whether these graphic granites are true eutectic mixtures, in that the ratio of feldspar to quartz represents the saturation point of each in the other so that both may solidify at the same time, is a question which this study was not designed to prove.

DETERMINATION OF QUARTZ CONTENT.

The determination of the quartz content in the graphic granites by synthesis resulted as follows:

Graphic granite A was very fine grained. A block of this material was crushed and then cleaned as completely as possible of free quartz. The fact that the quartz present was of the smoky variety made its detection less difficult than would otherwise be the case. The pure feldspar was pulverized to pass a 200-mesh sieve and a series of mixtures with pulverized quartz prepared containing 5 to 35 per cent quartz. The mixtures were molded into cones of standard dimensions. This series was placed on a fire-clay slab, together with a specimen of the original graphic granite A and also a specimen of the pure feldspar A.

The pure feldspar deformed with cone 8. The graphic granite A deformed slightly above cone 8 and simultaneously with the mixture of feldspar A and 25 per cent quartz. A comparison of this data with the calculated norm composition shows that the discrepancy is not very great.

Graphic granite B was of medium size grain. A block of this material was crushed, cleaned, and pulverized in the same manner as graphic granite A. Specimens of the pure feldspar and the graphic granite and a series of feldspar-and-quartz cones were prepared and tested.

Pure feldspar B deformed with cone 8. Graphic granite B deformed with the mixture consisting of 70 per cent feldspar and 30 per cent quartz and at the temperature of cone 9. A comparison of this data with the calculated norm composition indicates a discrepancy of 2.4 per cent, as the calculated content of free quartz is 27.6 per cent.

Graphic granite C was coarse grained. A block of this material was prepared and tested in a manner similar in all respects to that followed with graphic granites A and B.

Pure feldspar C deformed midway between cones 7 and 8. Graphic granite C deformed between cones 8 and 9, but nearer cone 9 temperature. It deformed with the mixture of feldspar C and 30 per cent quartz. A comparison of this data with the calculated norm composition shows the synthetic mixture to be 2.6 per cent high.

This method of determining the quartz content of a pulverized feldspar is shown to be perfectly practical within general limits, but can not be depended on for determinations closer than 2 or 3 per cent. This discrepancy is possibly in part due to the fact that the quartz used in the synthetic mixtures was finer grained than the quartz contained in the ground graphic granite. This fact was proven by microscopic study of the fused cones, although the powdered materials were all thought before use to be of sufficiently uniform fineness.

In nature graphic granite is a mixture of feldspar and quartz in intimate crystalline relation, but both exist as distinct minerals. These graphic granites must be reckoned as mixtures of feldspar and quartz, which fortunately are remarkably constant for graphic granites containing feldspars free from lime and high in potash and low in soda. If the user of graphic granite will recalculate it in terms of feldspar and quartz and introduce it as such, much of the difficulty arising from its use will be overcome.

NORMATIVE COMPOSITION OF GRAPHIC GRANITES.

The compositions of 18 graphic granites, calculated into their mineral components as norms,[a] is given in the table following. This list, with the exception of Nos. 3, 4, 8, and 14, is discussed by Bastin.[b]

[a] For a discussion of methods of calculating the normative composition of a rock from the actual composition, as shown by chemical analysis, and the significance of the relationship, see Clarke, F. W., The data of geochemistry, U. S. Geol. Survey Bull. 491, 1911, pp. 404-406.

[b] Bastin, E. S., Geology of the pegmatites and associated rocks of Maine: U. S. Geol. Survey Bull. 445, 1911, pp. 41-42.

Composition of graphic granites calculated into their norm components.

No.	Locality.	Feldspar content.			Free quartz.	Reference.		
		Potash feldspar.	Soda feldspar.	Lime feldspar.		Designation of sample.	Bulletin.	Page.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*			
1	Hitteren, Norway	51.2	14.3	0.5	34.0	Bygden No. 8	U. S. Geol. Survey Bull. 445	41
2	Skarpo	58.2	10.6	1.7	29.5	Bygden No. 7		
3	Cathance, Me	51.1	16.9	.....	27.6	Graphic granite B	This bulletin	.....
4	Georgetown, Me	50.6	19.0	.....	27.4	Graphic granite C		
5	Reade	48.1	20.5	4.1	27.3	Vogt No. 4	U. S. Geol. Survey Bull. 445	41
6	Topsham, Me	54.4	18.5	.....	27.1	No. 1	do	124
7	do	55.2	18.5	.....	26.3	No. 2		
8	do	53.4	18.2	.....	25.8	Graphic granite A	This bulletin	.....
9	Voie, Arendal, Norway.	55.1	17.9	1.6	25.3	Vogt No. 1		
10	Hitteren, Norway	52.0	21.5	1.8	24.7	Vogt Nos. 2 and 3	U. S. Geol. Survey Bull. 445	41
11	Arendal, Norway	48.9	25.8	1.8	23.5	Vogt No. 5		
12	Bedford, N. Y	47.4	28.4	1.0	23.2	No. 3	do	124
13	Elfkarleo	59.2	19.4	.6	20.8	Bygden No. 6	do	41
14	Portland, Conn	51.2	29.2	.2	17.4	No. 4	do	124
15	Rodo	6.0	47.8	2.8	39.0	Bygden No. 9		
16	Ytterby	2.7	46.3	13.1	37.9	Bygden No. 11	do	41
17	Evje	8.5	51.9	7.9	31.7	Vogt No. 6		
18	Beef Island	3.8	55.5	22.4	18.3	Bygden No. 12		

The table discloses the fact that the ratio of potash feldspar to soda feldspar in graphic granite is generally greater than 2 : 1 and often reaches 3 : 1. In those samples in which soda feldspar is the prevailing type of feldspar the potash feldspar is present in very small amount only. The graphic granites 15, 16, 17, and 18 belong to a class entirely distinct from the others. A fact worthy of note is the small variation in norm content of potash feldspar in Nos. 1 to 14, inclusive. With the exception of Nos. 2 and 13, the potash feldspar content is between 47.4 per cent and 55.2 per cent of the graphic granite, whereas the soda feldspar in the same series varies from 10.6 per cent to 29.2 per cent. In the first 14 samples—that is, the graphic granites high in potash feldspar—only two contain more than 27.6 per cent free quartz and only two contain less than 23.2 per cent. Thus 70 per cent of the graphic granites studied contain 23.2 to 27.6 per cent of free quartz, a variation of 4.4 per cent.

PROSPECTING AND SAMPLING.

Too much emphasis can not be placed upon the importance of thoroughness in prospecting for feldspar and in sampling the deposit when located. Practically all the failures in feldspar quarrying are due to improper prospecting and sampling, which has led to an overestimation of the extent of the deposit and of the quality of material obtainable. In many instances the analysis of hand specimens taken in the course of ordinary prospecting have been made the basis of large investment and expenditures where the material of the grade sampled is so limited as to hardly justify a passing glance.

In prospecting for feldspar the geology and topography of the district must be carefully considered. If the country rock is more easily eroded than granite or pegmatite the dikes or sills are exposed above the surrounding country. If the country rock is more resistant to erosion than granite or pegmatite, the existence of the dikes or sills is indicated by depressions. Throughout the New England and North Appalachian States the former case prevails and in many places pegmatite rich in feldspar is exposed along the ridges or along the steep slope of the hills.

When such an exposure is found or a deposit of pegmatite is in any way discovered, the prospector should first ascertain the general nature of the walling rocks. From a hasty survey the existence of folding or faulting can be determined and also the deposit classified as dike or sill. An exposure may be either across the dike or along its strike and what may seem to be the face of a broad lens may be in reality only a thin sheet. With the formation identified as dike or sill the prospector should proceed to determine the strike and dip as well as the general dimensions of the deposit. To do this the overburden should be removed from the exposure until the full width of the deposit is bare. With the data thus obtained the apparent strike should be projected 50 feet and the deposit uncovered at that point. Sometimes this projected continuation of the dike will prove erroneous, hence it is advisable where the overburden is heavy to locate the dike first by drilling. Prospecting should be continued at intervals of not more than 50 feet in both directions from the original exposure, and if the deposit seems to vary greatly in dimensions the intervals should be reduced to 25 feet.

The location of the dike by drilling is only of value as a labor saver in determining where the cuts shall be made. The reason for this is obvious. The drill sample can merely indicate that the formation is of a granitic nature and shows little as regards size of grain or the extent to which impurities exist.

After locating the limits of the deposit therefore open cuts or at least a pit should be made in order to expose a reasonable area of the surface. These exposures should not be farther apart than 50 feet. The cutting of a trench across the entire deposit as compared with sinking a pit through the overburden has been proven by experience to be little if any more expensive, as the trenching can be done with plow and scraper, whereas in digging a pit most of the work is necessarily hand labor.

Which surface is exposed by this method depends on the nature of the deposit, if it is a dike the surface exposed represents the cross-sectional face of the deposit; if a sill the surface exposed is one of the walls and does not in any way represent an average of the deposit. The mode of procedure therefore depends upon the nature of the deposit.

SAMPLING A DIKE.

To sample a dike from the trenches cut, the most satisfactory method is as follows: Lay off the dike from wall to wall in 5-foot centers, beginning at a point 1 foot from the foot wall and placing the last center not more than 3 feet from the hanging wall. At each of these centers drill a row of three holes, 3 feet deep and 2 feet apart, on a 45° slope toward the hanging wall, the rows being at right angles to the trench wall. Charge each hole with one stick of "60 per cent" or one and one-half sticks of "40 per cent" dynamite, and tamp well with soft clay after attaching the detonator or exploder wire. Fire by whatever method is most convenient, but fire the rows in regular order, beginning with the one next the hanging wall. Much better results will be obtained if all the holes of a row are fired simultaneously. Each row should be carefully sampled and all loose débris cleaned away before the next round of shots is fired. As soon as the shots are fired, the loosened material should be removed and broken into pieces of approximately 3 inches diameter or less.

This material should include **all that is loosened by the shot**, but judgment should be used in handling it—for instance, a block of mica which was imbedded in the mass, but was entirely independent of the remaining material, should not be crushed and mixed with the other material loosened by the shots.

A careful record of the surfaces exposed should be made and especial emphasis should be placed on the gradation from the surface inward as regards size of grain and presence of associated minerals.

The material loosened by a row of shots should all be piled on a sampling cloth or wooden platform and thoroughly mixed, quartered, and two opposite quarters discarded. After mixing the remaining material thoroughly, it should be quartered, and two opposite quarters discarded. What remains on the cloth should be broken into pieces not to exceed 2 inches maximum diameter and the whole thoroughly mixed together. By repeated quartering this mass should be reduced to a sample of about 5 pounds.

In quartering especial care should be taken that the quarters discarded are entirely removed, because if some fine material is left on the sampling cloth each time, as is sometimes done by careless samplers, the resultant 5 pounds will contain an excessive amount of this fine material, which may have a different composition from the coarser material.

If the faces exposed by the shots indicate that the dike material improves rapidly with depth it may be advisable not to sample the rock next the surface, but to obtain the sample from the bottom of the holes. This can sometimes be done by striking with a heavy sledge the faces exposed in the bottom of the blast hole. If this is not effective a single hole may be bored in the bottom of the blast hole. This drill hole should slope 45° toward the foot wall, thus cutting under the face exposed by the first shot with the minimum depth of drill hole. A single hole 2 feet deep charged with one stick of "60 per cent" dynamite will generally move enough pegmatite to afford a good sample and this sample should be all removed and carefully sampled as explained above. After all the centers in all the trenches have been sampled in this manner, the depth of the dike is still to be determined. As this involves considerable expense for sinking shafts or cutting a tunnel, it may be advisable to first make or have made fire tests of the samples already taken. If the results of the tests prove satisfactory, the prospector is now ready to select a site for the test shafts or tunnel. The selection of this location will depend more or less on the topography of the country. If shafts are to be used at least two will be necessary and they should be at least 50 feet apart along the strike of the dike. One may be sunk at the natural place to open the dike, and the other should preferably be on higher ground. The shafts should be sunk not less than 25 feet into the dike material or until the grade of the product is proven too low for commercial use. The most convenient small shaft is a 3 by 6 foot rectangular shaft, with the larger dimension across the dike. In sinking such a shaft, frequent and detailed record should be made of the appearance of the rock, and at intervals not exceeding 5 feet a 50-pound sample should be taken, and each of these samples crushed and quartered to a 5-pound sample after the manner described above. If more than one band of the dike is exposed in the shaft, each band should be sampled separately.

TESTING FELDSPAR.

If a feldspar as marketed was the powder of a pure mineral, the chemical analysis would doubtless afford a reliable means of checking the various shipments and thus insure uniform results from its use. As the feldspar of commerce necessarily contains other minerals which are associated with it and as the term "feldspar" is used to cover a broad range of chemical composition, the safest course for the user who desires uniformity of results is to determine the chemical composition and also the physical properties of the feldspar. For the methods of chemical analysis of feldspars, the reader is referred to United States Geological Survey Bulletin 422.[a] The most important physical properties of feldspars are as follows: Temperature of deformation or fusion; rate of deformation; color when deformed and after complete fusion; shrinkage which its introduction imparts to a standard porcelain body.

TEMPERATURE OF FUSION.

Feldspars fuse at widely varying temperatures, owing to their great variation in chemical composition. When to this cause of variation is added that of an uncertain proportion of mineral other than feldspar, only a very general prediction can be made as to the physical and pyrometric properties of the mixture.

Fusion is a progressive process and covers the entire pyrophysical change from the solid to the fluid state. The only means of measuring the degree to which the process has attained is to determine the change in viscosity of the mass.

Measurement of the viscosity of fusion by means of physical apparatus is a difficult operation, and the apparatus at present available is not suitable for the use of any but highly trained experimentors. Fortunately for the practical man, as well as for the more highly trained investigator, there is a simple and accurate method of measuring viscosity change in the early stages of fusion which affords a reliable means of expressing the relative temperature and rate of fusion.

[a] Hillebrand, W. F., The analysis of silicate and carbonate rocks: U. S. Geol. Survey Bull. 422, 1910, 239 pp.

TESTING WITH STANDARD CONES.

The method referred to is standardization against standard pyrometric cones of known deformation temperature and rate of deformation. Deformation may be defined as the first visual evidence of fusion and indicates the reduction of viscosity to the point where the mass is no longer able to support its own weight. The rate of deformation evidences only the rate of fusion in its early stages, but by the method employed the possibility of error is reduced to the minimum.

The standard pyrometric cones are made from a series of mixtures of carefully tested and standardized materials similar to those employed in porcelain manufacture. They were first produced by Dr. Herman Seger under the patronage of the German Government. The temperature at which the cone deforms is regulated by its composition. Seger made a series of standard cones to fuse at intervals of 20° C. between 1,150° C. and 1,650° C., and numbered them 1 to 26. Later a series of standard cones for temperatures from 950° C. to 1,130° C. were devised by E. Cramer, an associate of Seger. The members of this series also fuse at temperature intervals of 20° C., and are numbered 010 to 01. A series of standard cones were later produced for temperature above 1,650° C., and these are known as Nos. 27 to 42, the latter being the fusing point of pure alumina. The temperature at which these pyrometric cones fuse is affected to a greater or less degree by the heat treatment which they receive, but with firing conditions constant they are reliable to within a few degrees.

The standard cones of the Seger series, which are the only ones in which the feldspar investigator is interested, are as follows:

Seger series of standard pyrometric cones.

Cone No.	Deformation temperature, °C.	Cone No.	Deformation temperature, °C,
1	1,150	12	1,370
2	1,170	13	1,390
3	1,190	14	1,410
4	1,210	15	1,430
5	1,230	16	1,450
6	1,250	17	1,470
7	1,270	18	1,490
8	1,290	19	1,510
9	1,310	20	1,530
10	1,330	26	1,650
11	1,350		

Cones Nos. 21 to 25, inclusive, have proved so erratic in their behavior under commercial firing conditions that their manufacture and use have been abandoned both in Europe and America. The temperatures between 1,550 and 1,630° C. have proved impractical, however, for ceramic firing and in commercial practice there is no demand for cones deforming between these temperatures.

The process of manufacture of these standard pyrometric cones is as follows: The various ingredients are weighed in proper proportion and thoroughly ground to a homogeneous mixture. This mixture is made plastic by additions of a solution of dextrine and pressed in molds. After molding, the cones are baked at a low temperature to make them strong enough to permit handling. The shape and dimensions of the dried standard cone are shown in figure 14.

The material to be tested is ground to an impalpable powder and by a small admixture of dextrine, cornstarch, or similar solution is rendered sufficiently plastic to permit of its being pressed into cones of the same shape and dimensions as the standard cones. After drying these cones are ready for test.

METHOD OF TESTING.

A slab of fire clay is prepared and into this the cones to be tested are embedded about one-sixth their height. The cones should be spaced as closely as possible and not interfere with one another in deforming. Standard pyrometric cones should be placed upon the same slab or on separate slabs, and in as close proximity to the cones being tested as safety of operation will permit. The slab and cones, after being carefully dried, are so placed in an inclosed muffle furnace that no direct flame can strike the cones and the temperature is gradually raised until the desired deformation occurs (Pl. I, *C*).

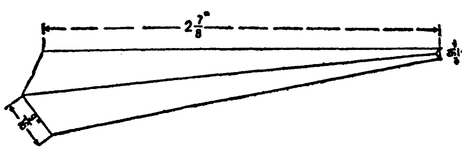

FIGURE 14.—Standard cone for deformation test.

A close watch must be kept over the process, as there are two stages to be observed—the shrinkage stage and the deformation stage. The first or shrinkage stage is well in advance of the deformation stage in some cases, and a considerable rise in temperature may elapse before any evidence of deformation is noticeable. Specimens that were removed from the furnace after reaching only the shrinkage stage have been found to be dense and slightly translucent, indicating that the process of fusion had begun in the individual particles but that nothing more than a cementing together of the particles had occurred. The shrinkage stage is characteristic of the standard pyrometric cones and hence these can not be used as standards by which the shrinkage may be gaged. However, as most standard cones do not begin to shrink perceptibly until heated within about 40° C. of the temperature at which deformation begins, it is practical to use as a standard for gaging the shrinkage one of the standard pyrometric cones No. 12 to No. 14, which will certainly not begin to shrink until any feldspars that may be used in ceramic manufacture are well advanced in the process of deformation.

In placing the cones on the slab of fire clay it is highly desirable to slant them all slightly and uniformly in the direction in which it is desired that they should deform.

The process of deformation begins when the first evidence of bending is discerned, and is completed when the point of the cone touches the surface of the slab on a level with the base. Stages of deformation beyond the latter point are not easily determined owing to uncertain effect of the supporting action of the plate on two points of the cone. The first evidence of deformation of the feldspar should be carefully recorded with data regarding the degree of deformation of the standard pyrometric cones against which it is being standardized. As its deformation progresses frequent records should be made both of the feldspar cone and the standard cones. This data is valuable in direct proportion as the number of careful readings, since these indicate the rate of deformation.

Time is a factor which must be carefully considered in expressing the temperature of deformation of any feldspar or standard cone. A careful record should be made of the time which elapses between the application of heat to the feldspar and standard cones and the beginning and termination of the deformation process. Also a record should be made of the rate of increase of temperature in the inclosure containing the cones. This data may be obtained by providing a series of standard pyrometric cones which deform at stated intervals from red heat to the critical temperature of the feldspar being tested.

USE OF PYROMETERS.

A more satisfactory means of procuring this data is by employment of one of the numerous pyrometers designed for temperature determination, many of which are equipped with an automatic recording device by which the rise in temperature is plotted on a sheet suitably prepared for such record. Pyrometers other than pyrometric cones may be classified as follows: (1) Thermoelectric pyrometers, (2) heat-radiation pyrometers, and (3) optical pyrometers. A brief description of these thermometers which has been given in Bulletin 53 [a] is included here:

[a] Watts, A. S., Mining and treatment of feldspar and kaolin in the southern Appalachian region: Bull. 53, Bureau of Mines, 1913, pp. 23–24.

THERMOELECTRIC PYROMETER.

The thermoelectric pyrometer is an instrument for ascertaining the temperature in an oven or kiln. It consists of a thermoelectric couple, made by fusing a platinum wire and a wire composed of 90 per cent platinum and 10 per cent rhodium, which is exposed to the temperature. The difference in temperature between the hot and the cold junctions of these two wires is proportional to the electric current generated, and this is recorded on a galvanometer. The deflection of the galvanometer varies with the current generated, and the dial of the galvanometer, being scaled in centigrade degrees, permits the operator to read directly the temperature of the furnace. Such an instrument is reliable to 3° C. under ideal laboratory conditions, and is reliable within 5 to 10 degrees under factory conditions. The electric pyrometer is highly satisfactory for use in testing feldspars, but as the deformation of a feldspar is a pyrochemical process, in which heat and time are factors, the time consumed in heating the sample to the deformation temperature should be considered in expressing the deformation temperature of any feldspar or feldspar mixture.

The thermoelectric pyrometer deteriorates rapidly at temperatures above 1,500° C., hence for testing kaolins and quartzes Seger cones or some form of heat radiation or optical pyrometer must be used.

HEAT-RADIATION PYROMETER.

In the heat-radiation pyrometer the heat radiated from an incandescent body, in the furnace or kiln, is focused on a thermocouple and the electromotive force generated is indicated by the deflection of an attached galvanometer, which is read on a dial scaled in centigrade degrees. The precautions that the operator must consider in using such a pyrometer are to have the incandescent object focused sharply upon the thermojunction and to have the image so focused of greater size than the junction.

Such a pyrometer is reliable only within 10° C. under the most favorable conditions; hence its use is little, if any, more satisfactory for temperature measurements than are the pyrometric cones.

OPTICAL PYROMETER.

The optical pyrometer of La Chatelier consists of a telescope that carries a small comparison lamp attached laterally. The image of the flame of this lamp is projected on a mirror at 45 degrees placed at the principal focus of the telescope. The images of the object viewed and of the comparison flame are side by side and are brought to equal intensity by suitable adjustment of the instrument. Under the most favorable conditions this instrument is subject to any error of vision of the operator and for high temperatures should hardly be expected to give results more accurate than 10° C.

As the deformation of feldspars may in some cases be completed within a temperature range of 5° to 8° C., the use of thermocouples or optical pyrometers does not furnish a graphic comparison. Seger cones, placed side by side with the sample to be tested, is by far the most satisfactory method of comparison, although it is always advisable to use a thermocouple or optical pyrometer to check the temperature of the deformation.

The cone of material of which the deformation point is to be determined is placed on a fire-clay slab to which it is made fast by means of a fusible slip or by packing clay about the base. If clay is packed about the base care must be used that the cone be set not more than one-fourth inch in the clay lest the deformation be retarded. If the deformation temperature is to be determined by means of cones, these should be placed about the cone to be tested and as near as possible without danger of contact when deformation begins. If the cones are not set exactly vertical, care must be taken that the same slant be given to all, otherwise the results will not be comparable.

As the rate of fusion is an important factor, the cones should be closely watched and the time at which each standard cone is exposed to the heat should be recorded, the time at which it begins to deform, and the time at which its point reaches the level of its base, the cone forming a semicircle. A similar record for the cone of the material being tested enables one to determine, by referring to the standard-cone record, the temperature of the beginning of deformation and also the temperature at which its point reaches the level of its base. The range of temperature between these two stages of deformation is very important as indicating the range of temperature within which the material under test will be valuable as a flux in pottery manufacture.

PROPERTIES OF FELDSPAR IN PORCELAIN MIXTURES.

The following description of methods of testing the pyrometric properties of feldspar is taken from Bulletin 53: [a]

TESTING BY MEANS OF STANDARD TRIALS.

The rôle of feldspar in the porcelain mixture is that of a cementing material or solvent, its activity depending on the temperature attained in the firing process. If the temperature only softens the feldspar the latter can do nothing more than bond the quartz and kaolin with which it is intimately mixed. If the feldspar is heated until it becomes fluid, it can take into solution part of the quartz and kaolin, and thus form a more or less homogeneous mass. Impurities in the feldspar may not seem very injurious in their action when the feldspar is tested alone, but may materially affect the speed of reaction and other properties of the feldspar when used in porcelain mixtures.

The action of a feldspar in porcelain mixtures is the only safe and proper basis for judging its industrial value. Experience has proved that it is not essential that the proportions of a porcelain mixture for testing be industrially correct but rather that those proportions be selected which will cause the ingredients to display most pronouncedly any faults that they possess. Thus an excess of feldspar will increase the tendency to warp and also to produce bad colors. For practical test the following proportions have been found most satisfactory: Feldspar, 20 per cent; kaolin, 50 per cent; and quartz, 30 per cent; mixed with 50 grams of water.

A standard for each of these materials should be selected from the best material on the market and should be thoroughly tested as to its physical and chemical properties. From these standard materials a standard trial mixture or blank should be prepared in the proportions given above and this standard trial should be tested in exactly the same manner as the mixture containing the material under test.

METHOD OF PREPARING TRIALS.

The standard plastic trials are produced by mixing the materials in the proportions given above. Especial attention should be given to the thorough mixing of these materials into a homogenous mass, as otherwise the trial mixture lacks uniformity and is unreliable. After being thoroughly mixed and kneaded the material is formed, by jiggering or by pressing into molds in such a manner that a product of varying thickness will be obtained.

For this trial a wedge-shaped rectangular block, which may be any desired length, is most satisfactory. If one edge is sharp and the other three-fourths of an inch thick the trial can be used for translucency and color tests; and by impressing the face with a metal die a record of linear shrinkage may also be obtained. Care should be observed that this mark for shrinkage or identification does not interfere with the translucency test.

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[a] Watts, A. S., Mining and treatment of feldspar and kaolin in the southern Appalachian region, Bull. 53, 1913, pp. 32–36.

For testing the feldspar a mixture should be prepared in every way similar to the standard trial or blank, except that the feldspar to be tested should be substituted for the standard feldspar. In the molding of trials the process employed in making the standard trials must be carefully duplicated if comparable data are expected. All test pieces should be conspicuously marked to insure identification.

As soon as trials are removed from the molds they should be placed where they may dry without warping, and when thoroughly dry the drying shrinkage may be determined by measuring with calipers the impression made by the die.

FIRING.

In firing the trials the temperature attained should be that to which the feldspar will probably be subjected in commercial work. For convenience this temperature may be safely assumed to be about that at which, in the deformation of the trial, the point reaches the level of the base, as described under deformation-point determination.

VITRIFICATION RANGE.

Vitrification range is that range of temperature within which the feldspar being tested produces a vitreous body that does not warp. The vitrification range of feldspar is determined by means of a bar one-half by one-half by 6 inches composed of a mixture similar to the standard porcelain mixture, except that the standard feldspar is replaced by the feldspar being tested.

This bar, after thorough drying, is so placed in the kiln that it is supported 1 inch from each end, leaving the 4 inches in the middle unsupported. The temperature at which warping begins marks the highest temperature that is practical for this feldspar in this proportion and is considered the maximum temperature of the vitrification range. The minimum temperature of the vitrification range is determined by firing to various temperatures the trials containing the feldspar being tested; they are then carefully weighed dry, and after standing for 24 hours in pure water are removed, carefully dried on the surface only, and reweighed. The increase in weight indicates the absorbed water content. The minimum temperature which renders the trial nonabsorbent is the minimum temperature of the vitrification range.

COLOR.

In the absence of a standard system of measuring color, the method employed is by comparison, using the standard porcelain mixture made and fired under comparable conditions as a standard.

TRANSLUCENCY.

Translucency is determined by placing the wedge-shaped translucency trials over a 1-inch hole in a box that contains a 16-candlepower electric lamp of constant brilliancy. The maximum thickness of the trial, expressed in centimeters, through which a No. 20 wire can be detected on the face of the trial next the lamp with the lamp 3 inches distant, is taken as a measure of translucency.[a]

SHRINKAGE.

Shrinkage is determined by measuring the length of the die impression made in the wedge used in the translucency test. The total shrinkage is the difference between the original length and the length after firing.

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[a] Weelaus, Charles, and Ashley, H. E., Report of the committee on the classification of white ware: Trans. Am. Cer. Soc., vol. 13, 1911, pp. 104-105.

TEST UNDER GLAZE.

An important property of all feldspars is their effect on the color of the body, both unglazed and glazed. Many porcelain bodies are of faultless color when unglazed, but when covered with a clear glaze the defects of the ingredients show, and the body as viewed through the glaze is so badly off-color that the commercial value of the ware is greatly reduced. Tests under glaze are therefore of much importance, and as the glazes used are of two classes—namely, raw-lead and fritted—it is advisable whenever possible to apply to the fired trials a thin coat of glaze. For convenience it is desirable to place a small quantity of each glaze on the same trial or test piece, in order that the effects of the different glazes may be most clearly compared. A small part of the trial should be left unglazed, in order that the effect that glazing has on the color may be determined by comparison.

For tests of materials in porcelain mixtures under glazes, those glazes should be chosen that are most likely to be used with the materials in commercial work.

For this test the following glazes have been found satisfactory and are recommenced for use at temperatures between cone 02 and cone 2—that is, approximately, 1,110° to 1,190° C:

Raw-lead glaze.

Molecular formula.

$$\left.\begin{array}{l}0.6\ PbO\\ 0.1\ K_2O\\ 0.15\ CaO\\ 0.15\ ZnO\end{array}\right\} 0.15\ Al_2O. \quad 1.5\ SiO_2,$$

Composition of batch by weight.

	Per cent.
White lead	51.81
Potash feldspar	18.60
Whiting	5.02
Zinc oxide	4.20
Kaolin	4.32
Flint	16.05
	100.00

This material is ground with water enough to produce a thin paste and is applied as a coat of uniform thickness to all the test pieces to be compared.

Fritted glaze.

Molecular formula.

$$\left.\begin{array}{l}0.13\ K_2O\\ 0.25\ Na_2O\\ 0.25\ ZnO\\ 0.25\ CaO\\ 0.12\ PbO\end{array}\right\} 0.22\ Al_2O_3\left\{\begin{array}{l}1.25\ SiO_2\\ 0.50\ B_2O_3\end{array}\right.$$

Composition of batch by weight.

	Per cent.
Melted frit	37.02
Potash feldspar	31.02
White lead	13.30
Zinc oxide	8.70
Kaolin	9.96
	100.00

Frit.

Molecular formula.

$$\left.\begin{matrix}0.5\ Na_2O\\0.5\ CaO\end{matrix}\right\}\left\{\begin{matrix}0.58\ SiO_2\\1.00\ B_2O_3\end{matrix}\right.$$

[Composition of batch by weight, raw.]

	Per cent.
Borax	69.25
Whiting	18.13
Flint	12.62
	100.00

This frit is melted to a glass, cooled, and ground to pass a 150-mesh sieve. The ground melted frit is added to the glaze in the proportion given above, and the mixture is thoroughly ground before being applied to the trials. The fritted glaze is generally applied in a thinner coat than that necessary for the raw-lead glaze.

BLANK OR STANDARD TRIAL FOR FELDSPAR.

The blank or standard trial for feldspar consists of the standard porcelain mixture, and contains the standard feldspar, kaolin, and quartz in the proportions specified.

The chemical composition of the standard feldspar is as follows:

Composition of standard feldspar.

	Per cent.
H_2O	0.35
SiO_2	71.75
Al_2O_3	16.70
Fe_2O_3	.14
TiO_2	.03
CaO	.25
MgO	.....
K_2O	8.59
Na_2O	2.99
	100.80

The standard feldspar has a deformation temperature range of 1,300° to 1,320° C. When fused it becomes a milky glass without any yellow tint.

In the standard porcelain mixture this feldspar produces a vitreous mass at 1,310° C. and at 1,350° C. shows no indication of warping. The color is a vitreous white without any distinguishable cream or blue tint. At 1,350° C. the feldspar produces a translucency of 0.65, and a total shrinkage of 15.6 per cent, 3 per cent of which is drying shrinkage and 12.6 per cent firing shrinkage.

QUARRYING AND QUARRYING METHODS.

The methods of quarrying dike materials vary greatly in different localities, owing to the wide difference in structure of different deposits and the varying amount of worthless material which must be handled.

Most pegmatite deposits outcrop along a part of their strike, and the common error of opening a quarry where the dike material is most easily and cheaply accessible, without due consideration for future operations, has caused many a venture to fail which with a little more care might have been a success.

Dikes rarely have vertical walls, and if a dike is opened from the foot-wall side the removal of the material below the hanging wall may necessitate the handling of a large amount of hanging-wall refuse. In many cases the deposit may be as conveniently opened on the hanging wall, and the foot-wall material need not be disturbed, so that the expense of handling this material may be avoided.

Careful planning of the method of attack is especially necessary in dealing with the isolated lenses of foreign or wall material which are to be found in all dikes and sills, the removal of which often absorbs all the profit from the marketable material obtained.

The dikes often contain impure bands throughout their entire extent. If these impure parts are along the walls, the quarrying may be so planned that only at the entrance and in parts of the hanging wall need the impure material be disturbed. If the capping of the dike is worthless because of impurity, it may be removed first and the great annoyance of handling this refuse on the quarry floor with the marketable material be avoided.

Where there is a definite impure band in the heart of the dike it is often advisable to remove the dike material only on one side the impure band and leave the other part until the band can be separately removed without serious difficulty.

The reason for working a quarry in such an irregular manner is evident if the expense of sorting the quarried products by hand is thereby avoided. Where biotite or tourmaline is scattered throughout the deposit and hand sorting of all marketed material is necessary, it would hardly be advisable to quarry the two sides and the impure band separately.

THE OPENING OF A QUARRY.

Careful consideration should be given to the opening of a quarry in order that the material may be handled as economically as possible. This consideration may involve opening the deposit at a point widely removed from the easiest point of attack.

Where the strike of the deposit follows the face of a hill and the deposit has been proved over a considerable area, the opening cut should be made across the entire width of the dike. From this crosscut entrance the deposit may be worked across the entire face. Only by this method can the production be maintained uniform for any great period of time.

If the deposit strikes across the hill it is necessary to confine operations to one face only, except in extraordinary cases where both ends of the deposit are so situated that quarrying may be carried on equally well from either end. In most cases one face presents greater advantages. If the hillside has a gradual slope, it is often practical to work the deposit on an upper level until a sufficient area is provided for convenient operation and then at a considerably lower level make a new opening, and thus increase the production over that possible from the single opening.

The quarrying of dike materials may be conveniently divided into two classes—(*a*) quarrying the part above water level and (*b*) quarrying the part below water level.

Such a classification is necessary, owing to the many special problems and considerations connected with quarrying below water level; also the added cost of getting out the rock. Many quarries which belong in class (*a*) are forced into class (*b*) because of mistakes made in opening the property or of improper methods of quarrying.

Where the dike is so located as to fall into class (*a*) the operation of quarrying consists in (1) removing the overburden, (2) quarrying the dike material by benches, (3) sorting the loosened material, (4) removal of the marketable and refuse material from the quarry, (5) handling of the marketable material between quarry and mill.

REMOVING THE OVERBURDEN.

The removal of overburden from a feldspar deposit is a subject which deserves especial consideration because careless stripping has caused more trouble than almost any other feature of quarrying. The operator is inclined to think that the overburden, being soil, will not contaminate the rock feldspar and, hence, may be allowed to wash down the face of the quarry or lie in heaps on the half-loosened feldspar masses about to be crushed for the mill.

The most injurious impurity with which the manufacturer of pure white pottery material has to deal is oxide of iron. The ordinary surface soil contains considerable quantities of oxide of iron in an extremely fine state. When this soil washes or caves down onto the masses of feldspar, this iron is infiltrated into the crevices and also coats the exterior of the rock. Subsequent knocking about prior to pulverizing does not remove the iron and it is pulverized with the feldspar, producing a product apparently white, but which develops numberless gray and brown specks on firing. Increased care and thoroughness in the removal of overburden is especially commended to the consideration of the quarry operators.

The overburden should be removed for a width of 20 feet from the quarry face. If the depth of the overburden is great, it should be stripped back far enough to insure against any slides falling into the quarry. At a short distance from the quarry face an ample drainage ditch should be cut to divert surface water from the quarry.

The overburden can generally be removed by plow and scraper when removed well in advance of the quarrying, and this method is much more economical than removal by hand, as is necessary when the overburden is allowed to remain until the quarried face is within a few feet of it.

QUARRYING THE DIKE MATERIAL.

In quarrying the dike material the depth and width of the benches will depend on the texture of the pegmatite; in most cases the best depth for drill holes is found to be 6 to 10 feet. The holes should be not more than 3 feet apart. The width of the bench should never be less than 4 feet, and 6 feet is a more economical and convenient width for drilling. It can be readily understood that, as the drilling of the holes is the most expensive item of the quarrying, the greatest possible amount of rock must be moved per hole drilled, provided the bowlders loosened shall not require subsequent drilling to bring them to a convenient size for handling.

The entire length of the bench should be drilled and loaded and the complete string of holes shot at one time. This is naturally more effective than where each hole is fired separately.

The diameter of hole is generally 2 inches, and the explosive used varies from "40 per cent" to "60 per cent" dynamite. In one instance "30 per cent" dynamite is reported as being used. For a 10-foot hole on a 6-foot bench, where a string of holes 3 feet apart are drilled, a charge of six sticks of "40 per cent" or four sticks of "60 per cent" dynamite is the normal charge per hole. The detonators caps used are Nos. 4, 5, and 6, the No. 6, however, being now almost universally used. Electric exploders are now almost universally used in feldspar quarries.

The breaking of the feldspar into coarse lumps instead of fine material has come to be general quarry practice except where the amount of impurity present makes close inspection necessary. The coarse material can be handled much more economically than fine material and can be crushed with little added expense. When the lumps fail to break readily, a small adobe (mud-capped) or a short-hole shot will quickly and economically reduce them to a convenient size for handling.

When a bench has been shot down and the coarse lumps reduced by sledge or explosive to a convenient size for handling, drilling may begin on the next bench while the fresh material is being removed from the quarry.

A much neglected but very important point in the successful operation of a quarry is the maintenance of a smooth and clean quarry floor. All the expense of maintaining a good floor is repaid by the economy of handling the material in removing it from the quarry.

SORTING THE MATERIAL.

The operation of sorting the feldspar and removing, by cobbing, any impure parts which are found adhering to otherwise pure feldspar is a task of varying importance in different quarries. In some instances the entire quarried product is removed from the quarry and sorted in sheds or on convenient piles and the refuse returned to the dump in a worked-out part of the quarry.

In most cases the extra handling of this impure material would add much to the cost of production, and the common practice is to load only the reasonably clean feldspar into the conveyance for removal from the quarry, the more impure material being conveyed directly from the bench face to the dump.

The moving of the broken rock from bench faces to bin or dump is a considerable problem. Within the Maine and Connecticut feldspar-producing district several quarries are using light hopper cars of the side-dump type that run on a track and are drawn by horses. The other quarries use the ordinary dump cart drawn by horse or handle all material in wheelbarrows.

None of the feldspar quarries of Maine and Connecticut has railroad connection to the quarry, and only one has harbor facilities without a considerable wagon haul. The expense of loading and unloading and the cost of hauling add considerably to the cost of the feldspar at the mill.

If the roadway from the quarry to the bins and dump can be maintained at a slight incline, so that the material can be handled by gravity, a considerable saving can be effected; and if in addition to this a dump-car system is employed, the cost of hauling and handling can be greatly reduced. No universal system can be offered for such operation, however, as no two feldspar properties have sufficiently similar surroundings to permit of a standard system.

QUARRYING FELDSPAR BELOW WATER LEVEL.

Where the deposit is below the level of a neighboring stream or body of water, or so far from the slope of the hill as to render a horizontal entrance impracticable, the dike must be opened from above. Fortunately such deposits are exceedingly rare, and as yet few such operations have been attempted. Most operations which fall in this class have been opened above water level, and when lower levels were reached pumps have been resorted to instead of cutting outlets at lower levels. When the working level reaches a point 30 feet below the outlet and the suction pump can no longer lift the water, under even the most favorable conditions, more expensive pumps are installed or a relay system of suction pumps is used.

The greatest expense of quarrying below water level consists in lifting the quarried rock to the surface. The great area being worked practically necessitates conveying the material to a central point, from which it is elevated. This extra handling adds to the expense. The actual cost of removing water or of elevating material does not render this method of quarrying excessively expensive, provided it is conducted in an economical manner and the deposit contains a sufficient quantity of marketable material to justify the installation of the necessary equipment.

Many of the feldspar deposits of Maine and Connecticut are isolated lenses and contain only a few hundred tons of merchantable feldspar. These are worked as shallow pits and the water which naturally drains into them is removed by siphon. When the feldspar has been removed the operator abandons the pit, which fills with water and adds another to the hundreds of small lakes which dot the country.

DRAINING THE QUARRY.

Although the amount of water to be removed from the average feldspar quarry is almost insignificant compared with that removed from most metal mines, the removal of water has been a source of great annoyance and excessive expense in many quarries. The custom at many of the smaller quarries of bailing the pit and hoisting the water with the apparatus used for hoisting the feldspar is followed in some of the larger ones, but the amount of manual labor required prohibits this method, except in emergency cases or where the quarry has been idle and, having filled with water, must be unwatered before quarrying can be resumed.

METHODS OF DRAINAGE.

The method to be selected in dewatering a mine is a matter which has received considerable attention from mining engineers, and a brief survey of the methods for removing water will be of interest.

SIPHON.

The siphon is the simplest and cheapest system of raising water if conditions are such as will permit of its use. The pipe is ordinary service pipe with tight fittings. At the outlet end is a valve which is the full size of the pipe, and above this valve is an attachment for a substantial hand pump or small power pump for starting the siphon. To avoid the labor of starting the siphon at frequent intervals it is necessary to observe when the water has been almost entirely removed from the quarry and shut off the valve at the outlet end of the pipe, leaving the siphon full of water. For convenience it is also wise to have a well or sump in the quarry and drain all the workings into it. A siphon is not possible except where the outlet end of the pipe can be well below the intake.

PUMPS.

STEAM PUMP.

The steam suction pump is the commonest form of pump used in connection with quarrying. The custom of placing the pump outside the quarry in many instances reduces its efficiency, because the weight of the column of water almost totally overcomes the suction. If the pump is placed on the quarry floor and the steam pipe is properly covered to prevent radiation, its efficiency should be greatly increased, because it then acts as a force pump. Where the floor of the quarry is liable to be flooded it may be advisable to place the pump on a ledge above the floor, but as low in the quarry as practicable.

CORNISH PUMP.

The Cornish rod pump is considered the cheapest means of lifting water where the quantity is sufficient to justify such an installation. This system of pumping can be worked at almost any depth, and, although its use is at present confined chiefly to deep mines, it would doubtless prove satisfactory where the quantity of water to be lifted is large.

COMPRESSED-AIR PUMPS.

Compressed-air pumps have little to recommend them for use in quarries unless the drills are operated by this power. If the amount of water does not necessitate continuous pumping, it is often practicable to drive a pump by this power when the drills are not running.

ELECTRICALLY DRIVEN PUMPS.

A pump driven by an electric motor has the advantage of being easily moved, and where hoists, trams, etc., are motor driven, the employment of this type of pump for hoisting water is thoroughly practical.

CAUSE OF PUMP TROUBLE, AND REMEDY.

The cause of practically all the trouble with pumps about quarries is the clogging of the valve in the suction end of the pump by particles of refuse. The remedy for this is a strainer attached to the intake pipe. This strainer should have sufficient openings to admit several times the amount of water necessary to supply the pump, because parts of the strainer may become temporaily clogged and the resistance to the flow of water is at all times considerable when admitted through such small openings. A reduced flow to the pump naturally reduces its efficiency.

HAULAGE METHODS IN QUARRIES.

The ordinary practice of hauling the quarry products to a central point by car or cart and there transferring to an elevator which lifts to the surface is admittedly an uneconomical method of handling and is daily becoming more so as the cost of labor increases. Economy of handling requires that the material be transported from quarry to mill or railroad without any transfer on the way and with minimum attention.

Any one of many different systems of haulage can be used, but the choice must depend on the conditions under which quarrying is carried on and especially on the topography of the country to be traversed.

The first and vital consideration is the extent of the deposit to be worked and the rapidity with which the material is to be handled. Any haulage system involves a considerable outlay, hence where the deposit is small or only a few tons are to be handled daily, a large and expensive equipment is not advisable.

Where the haul is level and the distance does not exceed 1 mile, the use of animals has proven as cheap a power as any, but the haul must begin at the working face of the quarry so that transfer is eliminated.

Where the grades exceed 5 per cent and the haul does not exceed 1 mile, rope haulage has been found an extremely satisfactory and economical system for elevating the material, but requires careful engineering in designing the equipment, especially where a short rise is followed by a long drop. If there is a continuous rise from quarry to terminus the system is especially worthy of consideration.

LOCOMOTIVES.

Steam locomotives are the most economical of all locomotives as regards fuel, provided the grades do not exceed 3 per cent, and are also the cheapest locomotive to install but are somewhat more expensive than other types as regards maintenance and depreciation.

Electric-locomotive haulage is the most modern and in many respects the most economical system. The power may be developed by a waterfall or otherwise at any convenient place and transmitted at high voltage on small wires to the property. Here it is stepped down to the working voltage, and where used at 250 to 500 volts the efficiency attained as regards power consumed is shown to exceed 90 per cent. One of the advantages of the electric locomotive is that it can be used in small units—that is, in moving loads about ton size—and where a heavier load is to be handled two locomotives may be worked in tandem and operated by the same engineer. This shows a big saving over the use of the large steam locomotive when handling small loads. The ordinary electric locomotive is not efficient, however, on grades of more than 3 per cent.

The gear-tooth electric locomotive is especially worthy of consideration for steep grades and where rope haulage is not practical. The gear-tooth type of locomotive is much lighter than the ordinary type and the haulage is dependent only on the power of the motor.

AERIAL TRAMWAYS.

Where the country is extremely rough and the construction and maintenance of a road would involve the building of bridges or the making of wide detours, the use of an aerial tramway recommends itself. The original cost of installation is generally less than with a roadway, and if properly constructed the cost of maintenance is far less. The supporting towers may be 100 or 1,000 feet apart, as the topography of the country demands. The operation of an aerial tramway on any but a straight line adds greatly to the expense and wherever possible curves and angles should be avoided.

Aerial tramways are of the two systems—single cable and double cable. The singles-cable system necessitates the return of all buckets over the sending cable, and this feature causes much delay and has resulted in the almost universal installation of the double-rope system where aerial haulage is used. The single-rope system consists of a single cable, which travels and to which the buckets are attached. The double-rope system has two fixed ropes which constitute the permanent way, and an endless traction rope which draws the buckets out on one rope and returns them over the other.

There are three types of double-rope aerial tramways:

1. The buckets are attached to the traction rope by a clip and are dragged along the stationary rope.
2. The bucket has a clip which seizes the traction rope and remains attached by friction.
3. The buckets are fastened permanently at fixed distances to the traction rope and are filled by a traveling bin which runs above and at the same rate as the buckets.

Each of the three types has many loyal followers and provided a good quality of material is used in the construction, an aerial tramway should be a very desirable and economical method of handling feldspar in the rough country where it is oftenest found.

PREPARATION OF THE FELDSPAR FOR MARKET.

CRUSHING AND PULVERIZING THE FELDSPAR.

The handling of the feldspar from the time it reaches the mill to the time it is delivered on board cars for shipment to the consumer consists of but two steps—crushing and pulverizing. The methods employed to accomplish these two results have changed from time to time, but the result has not changed materially.

DRYING THE CRUDE FELDSPAR.

When the crude feldspar reaches the mill it is often wet from snow or ice in winter or from quarry moisture in the spring. The general practice is to dry the crude feldspar in a vertical kiln or on a hot plate. Neglect of this point causes the fine particles to pack and later to cause trouble in the pulverizing process, but the most valuable result obtained is the elimination of fine dirt which sticks to the lumps of feldspar when wet but can to a considerable degree be shaken loose when dried and the feldspar handled with a steel fork.

Throughout the district investigated no attempt has been made to introduce the rotary drier which has proved so efficient in the drying of cement. This is explained by the fact that it is not necessary to use a drier more than about half the year. The saving made would, however, doubtless justify the installation of a rotary drier as the kiln and the dry plate are both uneconomical and necessitate extra handling of the feldspar.

CRUSHING THE FELDSPAR.

The dry feldspar is ready for crushing. The processes differ in different grinding plants, but they may be divided into two classes: (*a*) Those in which the crude feldspar, after being reduced by sledge to 3 or 4 inches diameter, is fed directly under the rolls of a buhrstone chaser, and (*b*) those in which the crude feldspar is fed into a rock crusher which reduces the feldspar to a maximum of 1 inch in diameter and then goes to the buhrstone chaser mill, which completes the crushing process.

ROCK CRUSHERS.

Rock crushers are of two kinds—jaw crushers, which are intermittent machines, and gyratory crushers, which are continuous machines.

The jaw crusher may be divided into three classes: (*a*) Those with the jaw pivoted at the top, (*b*) those with the jaw pivoted in the center, (*c*) those with the jaw pivoted at the bottom. Type *a*, which is pivoted at the top of the jaw (fig. 15), is the most commonly used in crushing feldspar. The type *b* crusher has a smaller capacity than *a* and no advantages. Type *c* is objected to because the crusher has a tendency to choke at the throat or outlet, and this mass of small rock particles chew into the jaw plates and add much fine iron or steel dust to the crushed product.

Gyratory crushers, like jaw crushers, may also be classed in three types as regards the crushing motion of the spindle: (*a*). Crushers having the greatest movement at the bottom on the smallest lumps, (*b*) those having an equal movement on all sizes of lumps, and (*c*) those having the greatest movement at the top on the largest lumps.

The chief objection to gyratory crushers is the fact that they all have a considerable grinding action which abrades the metal faces and produces more pulverized material than where a simple crushing action is employed. The jaw crushers also exert some abrading action, however, and no crusher having metal crushing faces is devoid of the objection of producing material more or less contaminated with small particles of iron or steel. The operator who employs a crusher of either the jaw or gyratory type has to deal with the problem of cleaning his crushed material of iron and steel particles. The simplest and surest method of accomplishing this result is to screen out all the fine material, because the metal is invariably ground off the plates in very small particles. The objection to this method is the large amount of fine material wasted, which in some cases is as much as 10 per cent of the rock crushed.

Apparatus to eliminate iron and steel particles from dry powdered rock have been only fairly successful and have not come into general

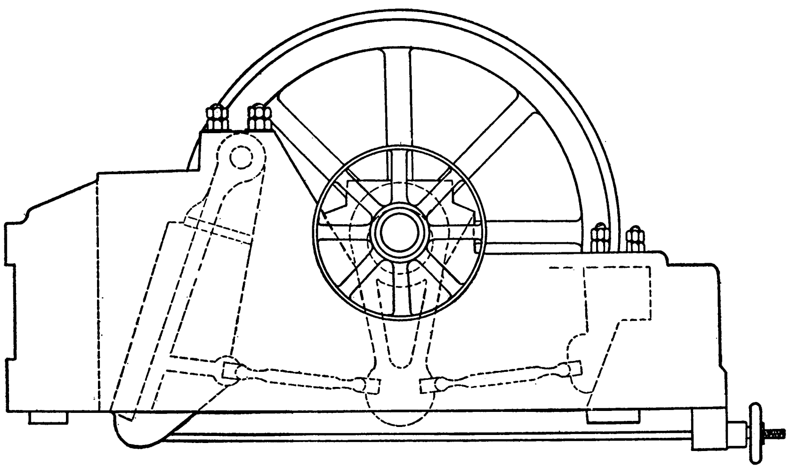


FIGURE 15.—Jaw crusher.

use. The most successful method is to use a system of magnets and to have the fine material in the form of a slime or slop. The expense of installing such an apparatus and of drying the cleaned slime will add somewhat to the average cost of crushing the feldspar but will show a big saving as against the rejection of all the dust material from the crusher.

Where the jaw or gyratory crusher has not been introduced the primitive chaser mill is used for crushing the crude feldspar.

THE BUHRSTONE CHASER.

The buhrstone rolls are immense granitic wheels 5 to 6 feet in diameter and 12 to 18 inches in thickness. Two such wheels are mounted on a horizontal shaft and travel around a vertical shaft on a bedplate of granite (fig. 16). This apparatus was for years the only method of crushing feldspar and is to-day in many plants the only apparatus employed for crushing the crude feldspar to a size suitable for grinding in ball mills. The quality of stone used for these great wheels is important because they wear away quite rapidly under the abrading action of the feldspar and any black mica, tourmaline, or other impurity which they contain would go directly into the powdered feldspar. Further, care must be exercised in selection of these rolls because many blocks contain soft spots, and these would wear more rapidly than the rest of the wheel, resulting in a flat wheel. When a wheel is not perfectly round and needs to be reground, which is quite expensive, the power required to turn it over the coarse feldspar becomes excessive.

The mode of feeding a buhrstone chaser is extremely simple and consists in throwing the lumps of feldspar inside the track of the wheels and against the central vertical shaft, from which the bedplate is sloped slightly so that the feldspar slides under the inside edge of the wheel and is crushed. The wheels continue to pass over it until it is forced out over the edge of the bedplate. Here it is collected and passed over a screen, the coarse material from which goes back under the rolls and the fine material goes to the ball mills. The old custom of crushing feldspar lumps 4 to 6 inches in diameter under these rolls causes much more rapid wear than if only small lumps are crushed, hence the willingness of the operator to risk iron contamination by introducing the jaw or gyratory crusher for preliminary breaking, in order to lengthen the life of the rolls, which are expensive and short lived at best.

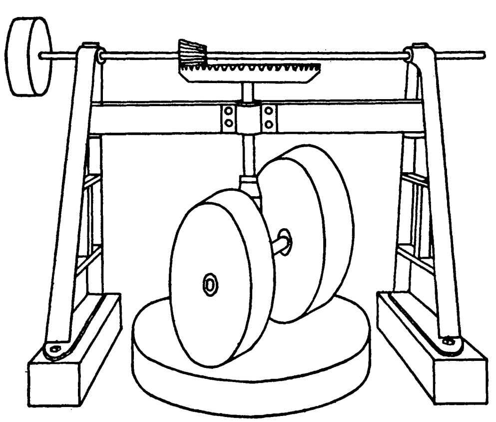


FIGURE 16.—Buhrstone mill.

If the feldspar has been subjected to a preliminary breaking before going to the chaser, the output of the chaser is greatly increased, but the treatment necessarily remains the same.

The sole objection to both the jaw and gyratory crusher is the contamination of the feldspar with iron particles. The introduction of buhrstone faces for the fixed and movable jaws should practically eliminate this difficulty. The buhrstone plates must of necessity be many times thicker than the steel plates which they would replace, but the frame of the crusher could be easily remodeled to provide for this.

Whatever the method of crushing, whether a combination of breaker and chaser, or treatment by the chaser alone, the feldspar must be reduced to a size which will pass a 10-mesh sieve dry in order to obtain an economical operation in the pulverizing mills.

SIEVING THE CRUSHED FELDSPAR.

For separating the coarse feldspar from the part ready for pulverizing, the revolving sieve or trommel is almost universally employed. The vibrating and shaker sieves are less efficient, owing to the presence of some flake mica, which wedges into the meshes of the sieve and prevents the fine feldspar from passing through. Every part of the sieve on the revolving type is inverted with each revolution, causing the mica particles to fall loose and pass out with the coarse material.

SEPARATING THE MICA FROM THE FELDSPAR.

The presence of the mica is considered by most users as highly objectionable, and this is doubtless true particularly when the flakes are of appreciable size. It would therefore seem highly desirable to remove the mica from the coarse material from the sieve before returning it to the machine for recrushing.

The mica in this material is chiefly thin flakes which have been completely separated from the feldspar with which the mica was originally intimately crystallized. A small amount will still adhere to feldspar particles, but this material can safely be returned to the chaser and the mica will probably be loosened in the next crushing. The separation of the mica from the crushed feldspar by an air blast or by flotation is perfectly feasible. The particles of feldspar in the crushed state approach cubes in form, whereas the mica is generally reduced to flakes, so that the mica may be carried by air or water much more readily than the feldspar and a separation effected. If no provision is made for removing the mica it will continue to be returned to the chaser and ultimately be pulverized. The presence of mica will not only reduce the quality of the feldspar, but its resistance to abrasion will increase the cost of pulverizing the feldspar.

PULVERIZING THE FELDSPAR.

The feldspar, after being crushed to a maximum size of 10 mesh, is ready for the pulverizer. The pulverizing may be accomplished by either wet or dry grinding, although the dry grinding process is now exclusively employed in the United States.

Wet grinding or pulverizing has been employed extensively throughout Europe. The machinery used consists of a broad shallow vat floored with smooth granite blocks and having a central vertical shaft with two horizontal arms. To each arm is attached a great granite or buhrstone block, which, as the shaft revolves, are dragged over the bed of the vat and crush the feldspar between them and the granite floor of the vat. In operation, the crushed feldspar is fed into the vat with sufficient water to produce a thin slip when the feldspar is properly pulverized. The traveling of the loaded arms around the vat keeps the water in motion and the feldspar goes into suspension as soon as it becomes fine enough. This method of grinding is expensive, but produces a very fine grade of product. It is still employed in many plants for the pulverizing of the materials to be used in glazes.

Wet grinding is also done in some plants in Europe by means of ball mills. This process does not differ materially from dry grinding in ball mills, as is described later. The essential difference consists in using water in the charged mill, in quantity sufficient to float the pulverized material, so that it does not interfere with direct contact between the pebbles and the coarse feldspar. The objection to wet grinding or wet pulverizing is the added expense of drying the pulverized material before it can be shipped any distance. In many European plants feldspar is ground only for private consumption, and in this case can be pulverized more economically than by the dry process. In some towns it is ground wet and sold locally in the wet state known as "slop," but this is impractical except where the haul is very short.

Pebble mills for dry grinding, as practiced in the United States, are of three different types: (*a*) Ball mills, (*b*) tube mills, (*c*) conical mills.

BALL MILLS.

Ball mills are the oldest form of this class of grinding machinery. They are made in all dimensions up to 8 feet diameter and 10 feet long. The construction of the mill is as follows: The cylinder is of heavy sheet steel riveted to heavy heads of cast iron, into which supporting shafts are shrunk. The cylinder is lined, both circumference and heads, with blocks of silex or vitrified porcelain. The grinding is effected by means of flint pebbles 2 to 3 inches in diameter, with which the mill is charged. The grinding action depends on the speed of revolution and the weight of the charge of pebbles. If the charge of pebbles and material to be ground fill only a small part of the interior of the mill, and the mill is run at a low speed, the pebbles will rise with the moving mill and roll back to the bottom only when gravity demands. If the speed is increased they are carried farther up and instead of rolling back, drop to the center of the mill. If the speed is too great, the pebbles are held against the circumference of the mill by centrifugal force and do not move, thus doing no grinding.

If the charge of pebbles and material to be ground fill the mill's interior above the center there is practically no action on the material except that of abrasion exerted by the pebbles sliding and rolling under the weight of those above. Different operators make very different claims as to what speed and charge are most economical and efficient, but it is generally claimed that for feldspar grinding the conditions last described, in which the action is largely abrasive, as the mill is more than half filled with pebbles and material, produces the largest tonnage of pulverized feldspar per horsepower consumed.

That period required to grind a given charge to pass any given sieve is determined by test, and the data obtained is made the basis

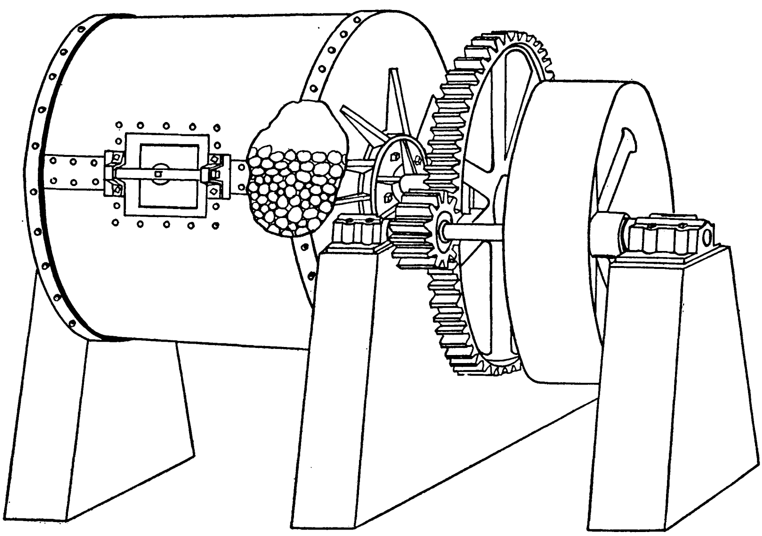


FIGURE 17.—Ball mill.

of operation. Most companies, however, sample and test the material by sieves before emptying the mill, and this practice is to be strongly encouraged, as only in this way can the operator be certain of the quality of the output.

The mill (see fig. 17) is charged and discharged through a door in the shell midway between the heads. The operation is periodic, the mill being stopped, the door opened, and the charge shoveled or dumped into the mill. The charge being ground, the mill is stopped only long enough to exchange the tight door for one full of holes of sufficient size to permit the powdered material to pass out, but to retain the grinding pebbles. The mill is set in motion and in revolving empties itself. This method of emptying the mill causes an enormous amount of dust throughout the plant and would seem to require that the mills be inclosed in dust-tight coverings. No such precautions are taken, however, and only in a few instances is any attempt made to box the mills in order to prevent the escape of the feldspar dust, which is the most valuable part of the product. The ground feldspar is generally shoveled into carts or wheelbarrows and removed to the stock bins or loaded directly into box cars for shipment.

TUBE MILLS.

Tube mills (fig. 18) are probably the most economical and in many respects the most efficient machine available for feldspar pulverizing. They are long steel cylinders with heavy cast-iron heads, and are of two types—namely, "axial supported," in which the mill revolves on two hollow steel trunnions, and "roller supported," in which the cylinder is fitted with a broad flat tire about its circumference near one end and a cog-faced tire near the other end. The machine rests on rollers and cogwheels, which provide the power for revolving the

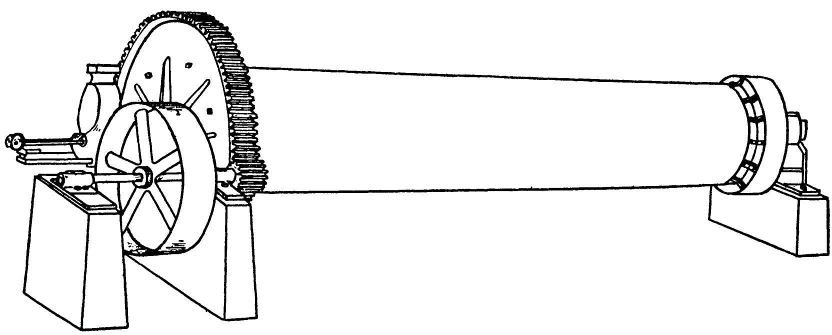


FIGURE 18.—Tube mill.

cylinder. The tube mill is lined, like the ball mill, with silex or porcelain blocks, and is charged with flint pebbles. The cylinder is set on a slight slope, so that the sand fed into it at the high end works its way down and out at the opposite end, being pulverized on the way. The feldspar is fed continuously to the mill through an opening in the center of the axle, and when it reaches the opposite end it passes out through the center of the axle at that end. In some mills the outlet is by small holes in the periphery of the mill. The number of revolutions which the material makes between entrance and exit and hence the fineness to which it is ground depends upon the slope of the mill. The quantity of pebble charge and the rate at which the material is fed to the mill are also factors that require attention, especially in the center discharge type. Too heavy feed forces the semiground material forward and out of the mill before it is properly pulverized, whereas the larger the pebble charge the smaller the charge of material that can be fed without causing it to rise above the overflow at the outlet.

CONICAL MILLS.

The conical mill was developed from the tube mill inasmuch as it consists of a long drum into which the material to be ground is introduced at one end and is expelled at the other end, being crushed in the passage by means of silex pebbles. The essential difference from the tube mill is the shape of the drum, which is a single or double cone. The effect of this cone is a classification of the grinding pebbles, the largest remaining in the part of the mill having the greatest diameter and the smaller pebbles grading themselves toward the outlet of least diameter. The material being pulverized also tends to classify itself according to size, not traveling to the outlet end until it has reached a certain fineness. These mills are built in a variety of diameters and lengths adapted to the reduction of different rock minerals. They are lined with silex blocks or vitrified porcelain in the same manner as are the ball and tube mills.

Conical mills have not up to the present time proved effective for the ultimate pulverization of feldspar, although they are reported as very economical and efficient in reducing the crushed rock to a size which enables the grinding period in the ball or tube mill to be reduced to the minimum.

BOLTING.

The practice of bolting the ground feldspar in order to remove the part which has not been sufficiently pulverized has never been practiced, although various attempts to introduce such a process have been made. The pulverized feldspar appears to take up a small amount of hygroscopic moisture, which causes it to pack on any fine sieve. If such a process was introduced it would necessarily have to be preceded by a thorough drying temperature well above 100° C. and the dry powder passed through the bolting mill at a temperature above 100° C. The maintenance of an equipment for such treatment is of doubtful value in view of the fact that where used for ceramic manufacture the pulverized feldspar is mixed with other materials which contain a small content of refuse that must be eliminated and the mixture receives a treatment which removes any coarse particles. It therefore appears sufficient to make a sieve analysis of samples carefully taken from the pulverized material and thus determine the exact degree of pulverization.

WATERING.

A common practice in many plants is the wetting down of the pulverized feldspar, presumably to prevent loss of the very fine part of the ground mineral. This practice is of doubtful value, as ground feldspar will quickly absorb from the air enough moisture to prevent its flowing. The addition of any water in excess of this amount must be paid for as feldspar, and freight from mill to user must also be paid on this water. Another and important consideration where feldspar is shipped in bulk in box cars is the tendency of damp feldspar to absorb stains from the boards which line the floor and sides of the cars.

Bagging the feldspar as it comes from the pulverizing mill has been found a very economical practice by some operators, as it reduces handling to the minimum if the plant is not equipped to mechanically convey the material to storage bins from which it can be loaded by gravity into cars for shipment. The protection from contamination which bagging insures is also worthy of consideration.

Where the feldspar is loaded loose in the car the practice of lining the interior of the car with cheap paper is recommended. If properly done, this paper lining will insure against loss through small openings in the floor and around the doors.

EFFECT OF TIME ON GRINDING OF FELDSPARS.

The degree of pulverization has long been known to exert a pronounced effect on the value of the feldspar in ceramic mixtures, but no specific data are available whereby a standard time of grinding can be chosen, for the reason that the degree of pulverization depends upon a number of factors.

Chief among these are the following: Speed (revolutions per minute) of the grinding cylinder, weight of the charge of pebbles in the cylinder, proportions of the various-sized pebbles in the cylinder, weight of the charge of crushed feldspar in the cylinder, degree of fineness to which the crude feldspar is reduced before being introduced into the cylinder, condition of the crude feldspar as regards temperature and moisture content, the physical properties of the particular feldspar being ground.

Any difference in the conditions under which grinding is effected would seriously affect the rate of pulverization.

The user of feldspar is concerned only with the degree of fineness to which the material is reduced, and the details of the grinding process need not interest him except as they influence the quality or price of the material obtained.

The proportions of the various-sized particles obtained by a standard system of grinding under uniform conditions and ground for stated lengths of time should be a valuable aid in choosing a standard degree of fineness. The increased pulverization obtained by grinding for longer periods should furnish data whereby the most practical degree of pulverization may be obtained and beyond which increased grinding does not produce a proportionate increase in fineness.

TESTS TO DETERMINE EFFECT OF TIME ON DEGREE OF FINENESS.

To determine these data a series of pulverized feldspar samples of a standard Maine feldspar were obtained. These had been pulverized under exactly similar conditions for definite lengths of time as follows: Sample of crude feldspar crushed by buhrstone chaser ready for ball mill; four samples of the same feldspar after grinding 6, 8, 10, and 12 hours in the ball mill, respectively.

CLASSIFICATION METHODS USED.

In order to determine the percentage proportions of the different sizes of grains contained in these samples, two systems of classification were followed: (*a*) Sieve, (*b*) elutriator.

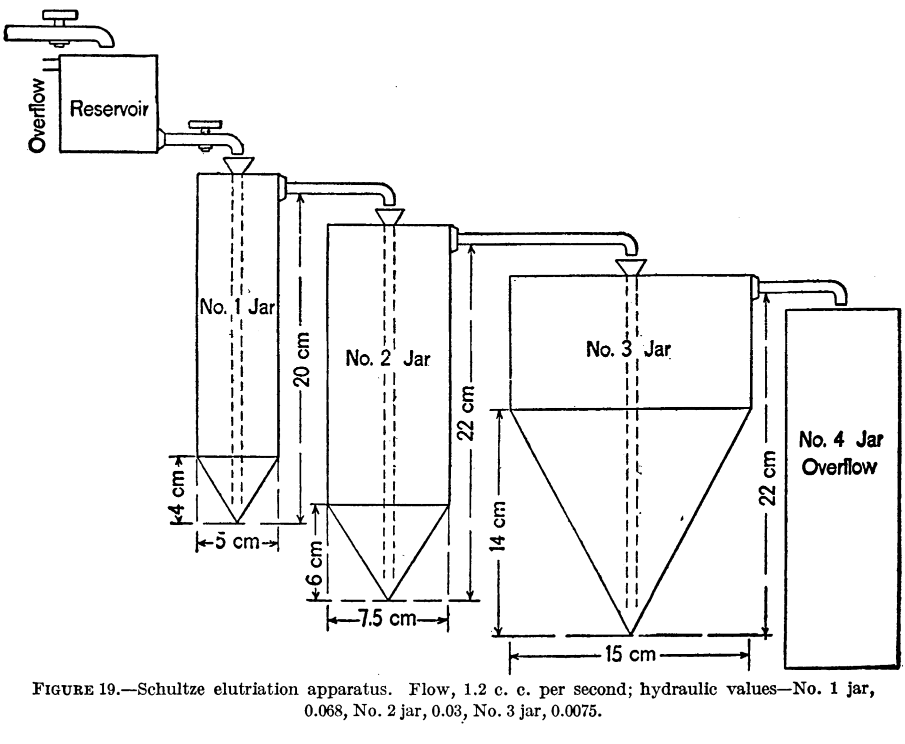


FIGURE 19.—Schultze elutriation apparatus. Flow, 1.2 c. c. per second; hydraulic values—No. 1 jar, 0.068, No. 2 jar, 0.03, No. 3 jar, 0.0075.

For the sieve classification bronze cloth sieves, ranging in fineness up to 330 mesh per linear inch were used. For classification of the material passing 330-mesh sieve the Schultze elutriator was employed.

SCHULTZE ELUTRIATION APPARATUS.

The Schultze elutriation apparatus consists of a series of three jars 5, 7.5, and 15 c. m. in diameter, respectively, with conical bases and straight sides. A quantity of feldspar is placed in the smallest jar, into the base of which water under a given head is admitted (fig. 19).

The current rising through the jar conveys all particles that it can support into a tube connecting with the base of the second jar. This jar being of greater cross-sectional area, the water rises through it at a slower rate than the water in the first jar. Some of the particles supported by the current in the first jar and carried over to the second are too heavy for the weaker current in the second jar and fall to the bottom. The overflow from the second jar is conveyed by a tube to the base of the third jar, which is of greater diameter than the second jar. In this jar the separation of still smaller particles is effected and material fine enough to be supported by the current flowing up through the third jar is conveyed to a fourth jar, where it settles. In this way the original sample is divided into four parts that differ in fineness.

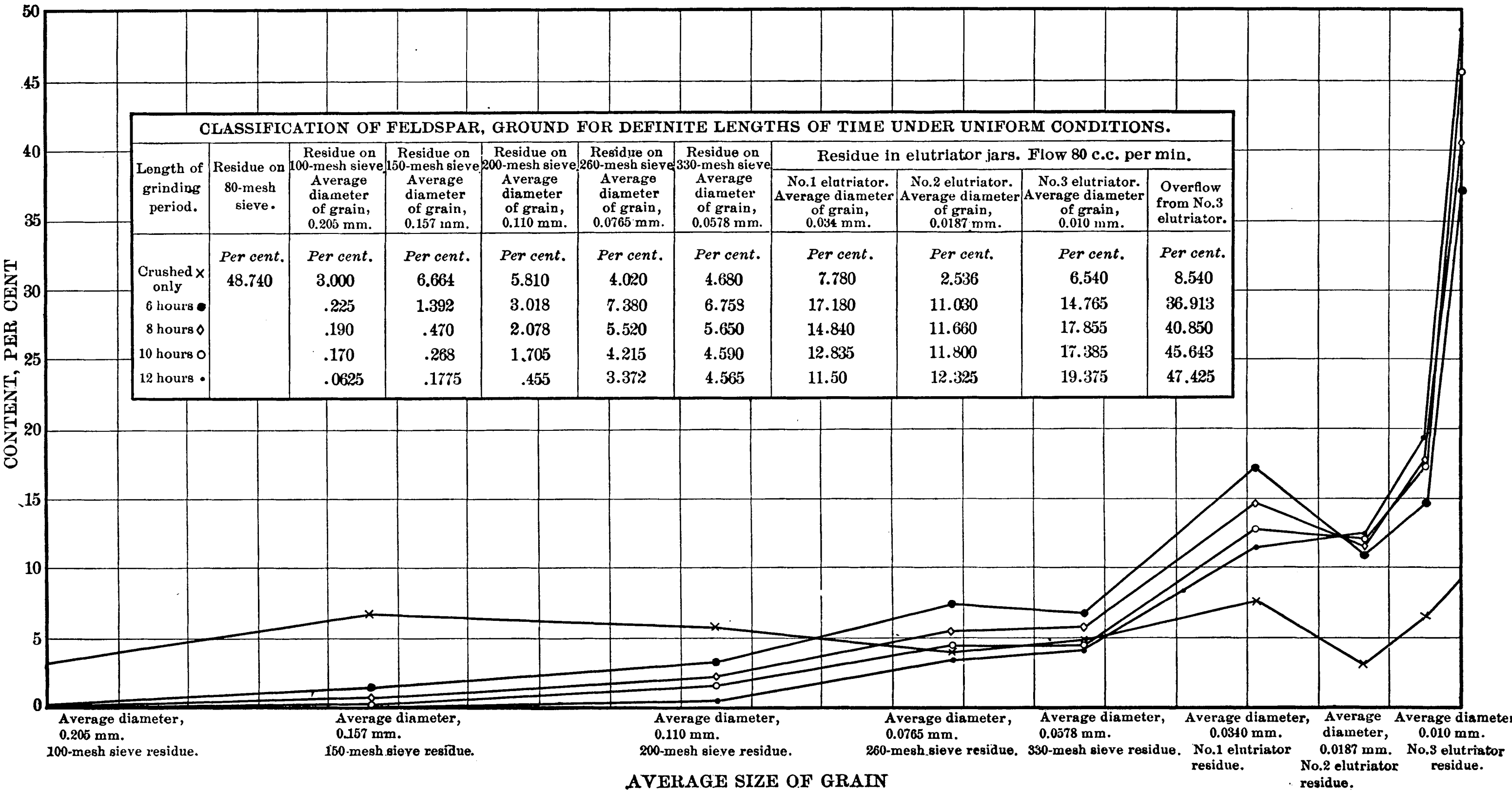
As the particles removed by the different jars of this apparatus are determined by their size and specific gravity and shape, and also by the rate of flow of water in the apparatus, the various divisions of particles are expressed in hydraulic values.

The hydraulic value of a given particle of any material is the rate of vertical flow of water, expressed in cubic centimeters per second, necessary to sustain that particle in suspension in water. By regulation of the flow in the elutriator, the following classification was obtained in the different jars. With an overflow of 80 c. c. per minute, No. 1 jar has a hydraulic value of 0.0679; No. 2 jar, 0.0302; and No. 3, 0.0075. The overflow from No. 3 jar furnishes a fourth classification. The size of grains obtainable with these different hydraulic values was determined by actual measurement of the classified material by the aid of the microscope. The classification was all effected in the wet way, and an abundance of water was employed to insure as perfect a classification as possible. In order to collect the fine slime which overflows from the last elutriator jar the water carrying it in suspension was collected in a large jar and to this was added about 2 c. c. of concentrated hydrochloric acid. The slime precipitates in about an hour and the excess water can be siphoned off. The classifications were dried at 100° C. and weighed, after which the microscopic measurements were made.

RESULTS OF TESTS.

Figure 21 shows that the increased pulverization obtained by longer grinding under these conditions is nearly proportional to the time of grinding. The choice of a rate of flow for the elutriator was slightly out of accord with the other classifications, but this was gaged by the size of grains desired in the different classes. It is especially worthy of note that the ratios between the proportion of material removed by each classifier was regular.

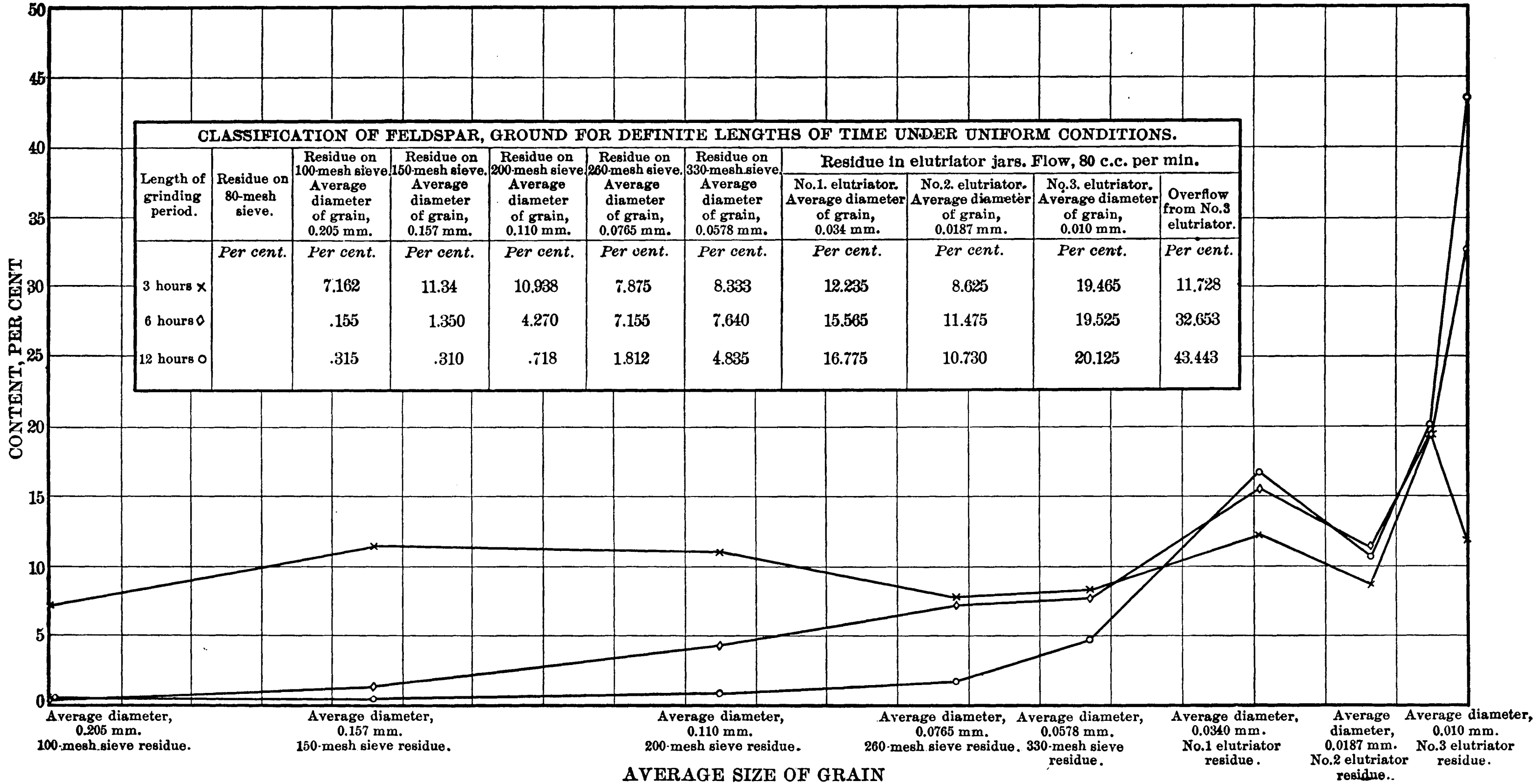
A similar investigation was conducted with samples of Connecticut feldspar ground under uniform conditions for stated lengths of time,



CLASSIFICATION OF FELDSPAR, GROUND FOR DEFINITE LENGTHS OF TIME UNDER UNIFORM CONDITIONS.

Length of grinding period.	Residue on 80-mesh sieve.	Residue on 100-mesh sieve. Average diameter of grain, 0.205 mm.	Residue on 150-mesh sieve. Average diameter of grain, 0.157 mm.	Residue on 200-mesh sieve. Average diameter of grain, 0.110 mm.	Residue on 260-mesh sieve. Average diameter of grain, 0.0765 mm.	Residue on 330-mesh sieve. Average diameter of grain, 0.0578 mm.	Residue in elutriator jars. Flow 80 c.c. per min. No.1 elutriator. Average diameter of grain, 0.034 mm.	No.2 elutriator. Average diameter of grain, 0.0187 mm.	No.3 elutriator. Average diameter of grain, 0.010 mm.	Overflow from No.3 elutriator.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Crushed × only	48.740	3.000	6.664	5.810	4.020	4.680	7.780	2.536	6.540	8.540
6 hours ●		.225	1.392	3.018	7.380	6.753	17.180	11.030	14.765	36.913
8 hours ◊		.190	.470	2.078	5.520	5.650	14.840	11.660	17.855	40.850
10 hours ○		.170	.268	1.705	4.215	4.590	12.835	11.800	17.385	45.643
12 hours •		.0625	.1775	.455	3.372	4.565	11.50	12.325	19.375	47.425

FIGURE 20.—Results of classifying test of Maine feldspar.



CLASSIFICATION OF FELDSPAR, GROUND FOR DEFINITE LENGTHS OF TIME UNDER UNIFORM CONDITIONS.

Length of grinding period.	Residue on 80-mesh sieve.	Residue on 100-mesh sieve. Average diameter of grain, 0.205 mm.	Residue on 150-mesh sieve. Average diameter of grain, 0.157 mm.	Residue on 200-mesh sieve. Average diameter of grain, 0.110 mm.	Residue on 260-mesh sieve. Average diameter of grain, 0.0765 mm.	Residue on 330-mesh sieve. Average diameter of grain, 0.0578 mm.	Residue in elutriator jars. Flow, 80 c.c. per min. No.1. elutriator. Average diameter of grain, 0.034 mm.	No.2. elutriator. Average diameter of grain, 0.0187 mm.	No.3. elutriator. Average diameter of grain, 0.010 mm.	Overflow from No.3 elutriator.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
3 hours ×		7.162	11.34	10.938	7.875	8.333	12.235	8.625	19.465	11.728
6 hours ◊		.155	1.350	4.270	7.155	7.640	15.565	11.475	19.525	32.653
12 hours ○		.315	.310	.718	1.812	4.835	16.775	10.730	20.125	43.443

FIGURE 21.—Results of classifying test of Connecticut feldspar.

and although a series large enough to make the data as comprehensive as in the foregoing investigation was not obtained, nevertheless the striking similarity of the results obtained and the fact that this series contains a three-hour sample, which is lacking in the other series, makes the presentation of the data advisable. The results are shown in figure 22.

DISCUSSION OF RESULTS.

The size of ball mill and operating conditions employed in the production of these samples varied considerably from that of the first series, but the ratio between the proportions of the different sized grains did not vary more than might be expected in a duplication of test on one mill.

The results of the three-hour grind are especially interesting because the percentage of the finest grains is lower than would be expected. The very low values obtained from these coarse feldspars when employed in ceramic mixtures are thus accounted for, as the distribution of different sized particles throughout the mixtures can not be sufficient to cause uniform vitrification of the mass.

As an indication of the influence of the size of grain on the temperature at which a feldspar may be expected to become active as a flux or solvent of other silicates, the products of the classification process were made into cones similar to the standard pyrometric cones and were subjected to deformation tests against standard cones. The results are shown graphically in figure 23.

The cones of that part coarser than 0.110 mm. would not hold their form during the early stages of firing, crumbling like sand as soon as the dextrine which was used in forming them burned away. Hence no data on the coarser grades of feldspar is available.

The results obtained indicate that the finest part deforms at least two cones (40° C.) earlier than the grains having an average diameter of 0.11 mm. and about one cone (20° C.) earlier than the grains having an average diameter of 0.0187 mm.

This data is the result of tests made on one feldspar only, but the pronounced variation in deformation temperature with variation of size of grain would indicate that a marked improvement in vitrifying power would result from increased pulverization regardless of the particular type of feldspar.

HANDLING THE FELDSPAR FROM QUARRY TO CONSUMER.

The cost of pulverized feldspar in the United States is materially increased by the repeated handling of the feldspar before, during, and after grinding. In some instances the feldspar is loaded onto wheelbarrows and removed to a clear space in the quarry, where it is unloaded and broken by sledge into pieces small enough for hand sorting. After hand sorting the good feldspar is loaded on a car or wagon and hauled outside the quarry. Here it is unloaded and

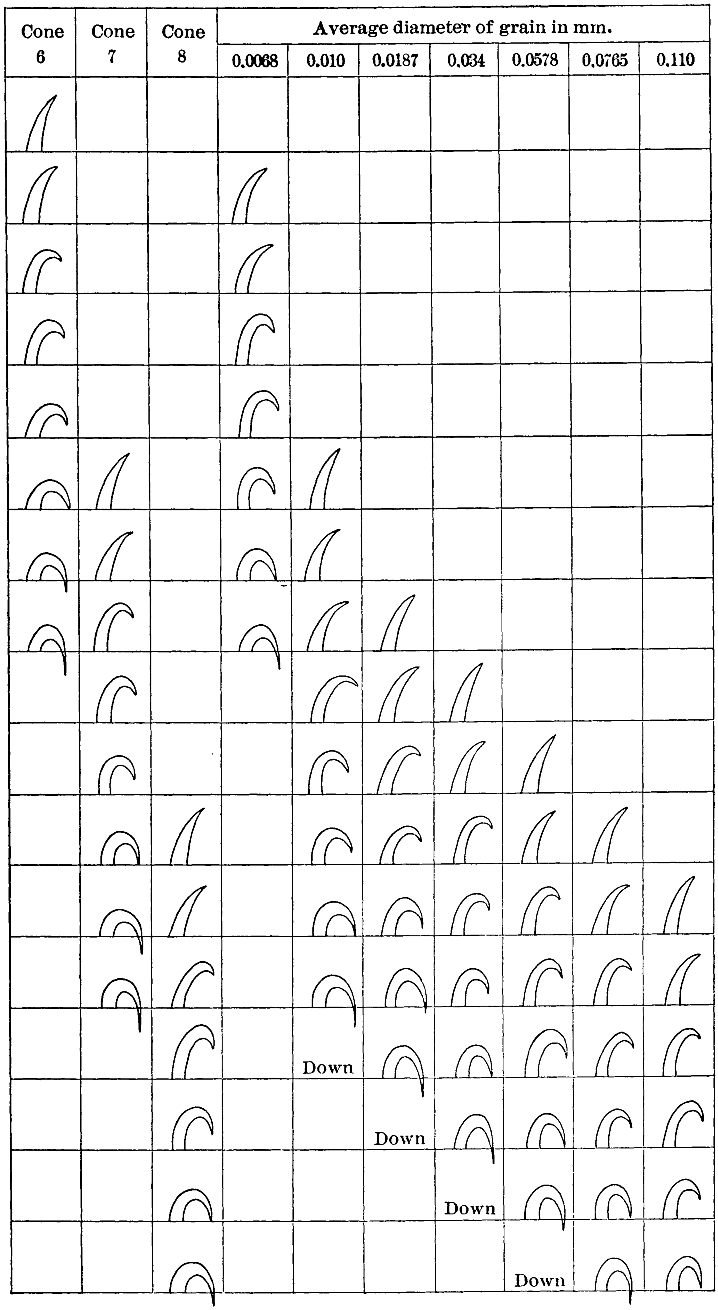


FIGURE 22.—Deformation tests of feldspars of different fineness.

stacked in bins. From these bins it is loaded into wagons, hauled to the railroad, and loaded into cars. After transportation to the grinding mill it must in some instances be loaded into wagons and hauled to the mill, where it is stored in sheds or bins on the ground level. Thus the crude feldspar is handled 8 or 10 times before it begins the grinding process.

From the sheds or bins the crude feldspar is loaded on wheelbarrows, cars, or wagons and hauled to the crusher, which is of either the jaw or roll type, dumped in a heap before this machine, and fed into it by hand as required. From the crusher it is generally elevated by conveyer to hopper bins above the ball mills, which are filled by removing a gate in the bottom of the hopper. After grinding in the mill the pulverized feldspar is discharged on the floor beneath the mill, shoveled into carts or cars, and wheeled to the stock bin, where it is stored until sold. The final handling consists in loading into wagons and hauling to the car, where it must be unloaded and shoveled or wheeled in wheelbarrows from the car entrance into the ends of the car. Thus the feldspar is handled perhaps seven times more, making a maximum of 17 handlings from the time it is shot loose in the quarry until it is delivered f. o. b. cars for the consumer.

In most of the feldspar mills in this country the total number of handlings does not reach the maximum, but where a saving is made at one point a loss occurs at another, so that the number of handlings rarely falls below 12. The installation of conveyers and tramways could save much of this handling, but the operator considers the investment too great to be considered in most cases. Furthermore, the uncertainty of the continuity of the dike beyond that actually exposed makes operators overcautious of expensive installations which can not be readily removed and erected on other properties.

CHEMICAL ANALYSES OF SAMPLES.

In the course of this investigation a large number of feldspar deposits were visited and samples collected. Some of these samples were subsequently analyzed and their pyrometric properties determined by testing in a standard porcelain mixture made as previously described.

The results of the analyses of some of the samples are given in the table following. In the first column of this table the numbers of the deposits correspond with those in Plates IV to VIII and in subsequent descriptions. Samples designated as A were analyzed in the laboratory of the Bureau of Mines at Pittsburgh, Pa.; those designated as B were analyzed by Robert Back, under the direction of C. L. Parsons, in the Washington laboratory of the bureau; and those designated C were analyzed for the Bureau of Mines by D. J. Demorest, of Ohio State University, Columbus, Ohio, in the laboratory of that university. The table follows.

TABLE 1.—*Results of analyses of feldspars and pegmatites.*

No. of deposit.	Laboratory.[a]	Character of sample.	Deposit.			Composition.										
			Town or place.	County.	State.	Ignition loss.	SiO_2.	Al_2O_3.	Fe_2O_3.	TiO_2.	CaO.	MgO.	BaO.	K_2O.	Na_2O.	Total.
						Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
2	A	Potash feldspar	New Castle	Lincoln	Maine		64.67	19.18	0.20		0.99	Trace.		12.76	2.54	100.34
11	A	do	Cathance	Sagadahoc	do	0.33	73.89	14.33	.16		Trace.	Trace.		9.2	2.14	99.87
14	A	Pegmatite	do	do	do		74.34	14.45	.14		Trace.	Trace.		8.63	2.00	99.56
14	A	Pure feldspar in graphic granite.	do	do	do		65.07	19.39	.10		Trace.	Trace.		12.58	2.52	99.66
20	A	Graphic granite	Georgetown Peninsula.	do	do	.30	74.53	14.26	.16		Trace.	Trace.		8.55	2.25	100.05
21	A	Feldspar	Phippsburg Basin	do	do	.25	64.90	19.75	.12		.00	Trace.		12.04	2.68	99.74
22	A	do	Auburn	Androscoggin.	do		67.81	18.55	.08		.21	.07		9.32	4.27	100.31
31	A	do	Hebron	Oxford	do		65.48	19.39	.08		.00	Trace.		11.51	2.85	99.31
33	A	Soda feldspar	Mount Apatite	Androscoggin.	do	.16	66.36	21.35	.12		1.10	.21		.73	9.74	99.77
35	A	Graphic granite	do	do	do	.75	71.55	18.11	.16		.46	Trace.		.64	8.72	100.39
43	A	Feldspar	Norway	Oxford	do	.13	64.97	19.48	.04		.00	Trace.		11.76	2.56	99.94
48	A	do	So. Glastonbury	Hartford	Connecticut		65.64	19.11	.14		Trace.	Trace.		12.58	2.32	99.79
50	A	do	Portland		do	.25	65.24	19.74	.12		.00	.00		11.84	3.04	100.23
53	A	do	Middletown		do		66.03	18.99	.08		.00	.00		10.96	3.12	99.18
58	B	Microcline	Crown Point	Essex	New York	.40	63.61	19.09	.43	0.02	1.73	.54	0.17	.15	14.07	100.21
59	B	do	Ticonderoga	do	do	.18	64.55	18.90	.36	.03	.51	.19	.19	12.32	2.88	100.11
59	B	Andesine	do	do	do	.58	59.35	25.30	.57	.03	6.43	.00	Trace.	1.35	6.26	99.87
62	B	Feldspar	Batchellerville	Saratoga	do	.26	65.14	19.38	.29	.01	.44	.14	.00	11.28	3.61	100.55
62	B	Salmon feldspar	do	do	do	.17	64.26	18.78	.43	.00	.33	.14	.00	14.15	2.01	100.27
66	B	Andesine	Cranberry	Fulton	do	.54	61.91	23.69	.40	.00	4.37	.13	.00	1.17	8.40	100.61
67	...	Feldspar	Bedford	Westchester	do	.28	69.45	16.76	.20		.45	.05	.10	2.60	9.80	99.69
68	B	Salmon microcline	do	do	do	.22	64.82	18.87	.29	.01	.23	.16	Trace.	13.11	2.70	100.41
68	B	Albite pegmatite	do	do	do	.40	73.88	15.73	.36	.01	.86	.36	.00	.48	7.97	100.05
71	C	Microcline	Darlington	Delaware	Pennsylvania	.12	64.70	19.60	.03	.00	.05	.00	.00	11.87	3.76	100.13
72	C	Microcline pegmatite	Chester Heights	do	do	.33	73.35	14.60	.06	.00	.06	.00	.00	9.11	2.00	99.51
72	C	Albite pegmatite	do	do	do	.42	74.60	15.66	.05	.00	2.75	.00	.00	.65	6.33	100.46
78	C	Buff microcline	Mendenhall	Chester	do	.21	64.36	20.01	.20	.00	.46	.00	.00	12.44	2.48	100.16
78	C	Albite pegmatite	do	do	do	.60	67.93	20.49	.30	.00	2.60	.00	.00	.80	6.95	99.67
80	C	Graphic granite	New Garden	do	do	.30	72.39	15.57	.20	.00	.13	.00	.00	9.55	2.27	100.41
81	C	do	Pomeroy	do	do	.24	67.87	17.82	.15	.00	.12	.00	.00	10.93	3.33	100.46
89	C	Albite	Sylmar	do	do	.83	67.47	20.05	.15	.00	.24	.00	.00	.86	9.74	99.34

89	C	Magnesium aluminum silicate.[b]	.....do...........	.....do......	.....do.......	17.30	45.46	13.49	.05	.04	.08	23.28	.00	.30	.16	100.16
96	C	Pegmatite..............	Marriotsville......	Howard.....	Maryland....	.39	65.83	19.48	.20	.00	.00	.00	.00	11.33	1.87	99.10
101	C	Microcline pegmatite....	Woodstock........	.....do......	.....do.......	.13	74.20	14.30	.20	.00	.00	.00	.00	9.48	1.59	99.90
101	C	Albite pegmatite........	.....do...........	.....do......	.....do.......	.76	65.32	22.00	.21	.00	3.78	.00	.00	1.06	6.89	100.02
105	....	Feldspar..............	Lowry............	Bedford	Virginia	.10	68.75	18.56	.03	Trace.	1.25	Trace.	....	6.85	4.29	99.83

[a] Samples designated A were analyzed in the Bureau of Mines laboratory at Pittsburgh, Pa., those designated B, in the Bureau of Mines laboratory at Washington, D. C., and those designated C by D. J. Demorest, at Ohio State University, Columbus, Ohio.

[b] Along walls of dike from which No. 89-a was taken.

FELDSPAR QUARRIES, MINES, AND PROSPECTS:

The feldspar deposits that were investigated during the course of this investigation are briefly described in the pages following. Their location is shown in Plates IV to VIII. The numbers used to represent the deposits correspond to those used in Tables 1 and 2, and in the detailed descriptions of the deposits.

TABLE 2.—*Location of the feldspar quarries, mines, and prospects, including some mica and gem mines, shown in Plates IV to VIII.*

No.	Deposit.	State.	County.	Location.
1	Pegmatite dike	Maine	Hancock	East Orland, in.
2	John Glidden property.	do	Lincoln	New Castle, 2 miles west of.
3	Abandoned quarry	do	do	Edgecomb, in.
4	Hull property	do	do	Do.
5	Noble prospect	do	Sagadahoc	Georgetown Peninsula.
6	Smith prospect	do	do	Do.
7	Alfred Graves quarry	do	do	Cathance, 2 miles north of.
8	Maine feldspar quarry	do	do	Adjoins quarry No. 7.
9	Maine graphic granite quarry.	do	do	Cathance, 2½ miles northwest of.
10	Trenton quarry	do	do	Cathance, 2 miles northwest of.
11	Old W. G. Willis quarry.	do	do	Cathance, 1 mile west of.
12	Old Golding quarry	do	do	Adjoins quarry No. 11.
13	New W. G. Willis quarry.	do	do	South of Nos. 11 and 12.
14	Fisher quarry	do	do	South of No. 11.
15	Maine Feldspar Co. deposit.	do	do	Topsham, 2 miles east of.
16, 17	Mt. Ararat quarries	do	do	Topsham, 1 mile north of.
18	Mason property	do	do	Riggsville, near, on Georgetown Peninsula.
19	Noble deposit	do	do	Riggsville, near.
20	Golding quarry	do	do	Georgetown Peninsula.
21	Joseph B. Perry quarry.	do	do	Phippsburg, near.
22	Pegmatite dike	do	Androscoggin	Auburn, 1½ miles south of.
23	do	do	do	South of No. 22.
24	do	do	do	East of No. 23.
25	Staple Point deposit	do	Cumberland	South Freeport, near, on Staple Point.
26	Old Knox quarry	do	Oxford	Dixfield, 3½ miles southwest of.
27	Mount Mica deposit	do	do	South Paris, 5 miles northeast of.
28	Buckfield district	do	do	Owls Head, north of.
29	Hooker Ridge dike	do	do	South Paris, 1½ miles east of.
30	No. 4 Hill quarry	do	do	Hebron, in.
31	Hibbs quarry	do	do	Do.
32	Mount Rubellite deposit.	do	do	Paris Hill post office, north of.
33	Pulsopher deposit	do	Androscoggin	Auburn, about 4 miles west of, on west slope of Mount Apatite.
34	Towne quarry	do	do	Near and southeast of deposit No. 33.
35	Greenlaw quarry	do	do	Auburn, 3½ miles west of, on top of Mount Apatite.
36	Maine quarry	do	do	Auburn, 3 miles west of.
37	do	do	do	East of quarry No. 36.
38	Pegmatite deposit	do	do	Auburn, about 3½ miles west of, on south slope of Mount Apatite.
39	Havey quarry	do	do	Auburn, 3½ miles west of, south of Mount Apatite.
40	Berry quarry	do	do	Adjoins Havey property.
41	Charles Sawyer deposit.	do	Cumberland	Auburn, 4 miles west of, at Rumford Junction.
42	Dow property	do	do	West of Sawyer property.
43	Stevens ledge	do	Oxford	Norway, 2 miles northeast of.
44	Curtis quarry	Connecticut	Hartford	South Glastonbury, 3 miles east of.
45	Wiarda quarry	do	do	South Glastonbury, near.
46	Old Wiarda quarry	do	do	South Glastonbury, 1 mile south of.
47	Old Eureka quarries	do	do	South Glastonbury, 1¾ miles south of.
48	Louis W. Howe quarry	do	do	South Glastonbury, 2 miles south of.
49	Andrews quarry	do	Middlesex	Rocky Hill, 4½ miles southeast of.
50	Eureka quarry	do	do	Portland, 2½ miles northeast of.
51, 52	River side quarries	do	do	Middletown, east of.

TABLE 2.—*Location of the feldspar quarries, mines, and prospects, including some mica and gem mines, shown in Plates IV to VIII*—Continued.

No.	Deposit.	State.	County.	Location.
53	Consolidated quarry	Connecticut	Middlesex	Middletown, 3 miles east of.
54	Bidwell quarry	do	do	Middletown, 2½ miles south of.
55	Hallberg deposit	do	do	Middle Haddam, 2 miles southeast of.
56	Middle Haddam quarry.	do	do	Middle Haddam, 1½ miles southwest of.
57	Haddam Neck quarry	do	do	Haddam, near.
58	Crown Point quarry	New York	Essex	Crown Point, 2 miles southwest of.
59	Barrett quarry	do	do	Ticonderoga, 1¾ miles north of.
60	Ticonderoga quarry	do	do	Ticonderoga, 1 mile southeast of.
61	Corinth quarry	do	Saratoga	Corinth, 2½ miles southwest of.
62	Batchellerville quarries.	do	do	Batchellerville, 2 miles north of.
63	Herbert Snell property	do	Hamilton	Northville (Fulton County), 4 miles north of.
64	Rhodes quarry	do	do	Northville, 3 miles northeast of.
65	Gifford prospect	do	do	Northville, 1½ miles west of
66	Tyrol Mountain quarry.	do	Fulton	Cranberry, 2½ miles west of.
67	Bedford quarry	do	Westchester	Bedford, 1 mile east of.
68	Kinkel quarry	do	do	Near and east of Bedford quarry.
69	Hobby quarry	do	do	North Castle, in.
70	Bullock quarry	do	do	½ mile west of Hobby quarry.
71	Darlington quarry	Pennsylvania	Delaware	Darlington, 1 mile northeast of.
72	Chester Heights quarry.	do	do	Chester Heights, near.
73	Bunting quarry	do	do	Chelsea, near.
74	Halsey quarry	do	do	Boothwyn, 1 mile northwest of.
75	Boothwin quarry	do	do	Boothwyn, ½ mile west of.
76	Brandywine Summit quarry.	do	do	Elam, at.
77	Old Walker quarry	do	Chester	Mendinhall, 2 miles east of.
78	New Walker quarry	do	do	About 300 yards southwest of Old Walker quarry.
79	Embreeville quarry	do	do	Embreeville, near.
80	Lafferty quarry	do	do	New Garden, 2 miles southeast of.
81	Meredith quarry	do	do	Pomeroy, 2½ miles north of.
82	Chatham quarry	do	do	Chatham, ¾ mile northeast of.
83	Jenkins quarry	do	do	Toughkenamon, 1¼ miles east of.
84	Carpenter quarry	do	do	Toughkenamon, 1½ miles north of.
85	Thompson quarry	do	do	Baker, ¾ mile east of.
86	Hicks quarry	do	do	Avondale, 2 miles north of.
87	Pennsylvania quarries	do	do	Baker, near.
88	Cooper quarries	do	do	Avondale, 1½ miles southeast of.
89	Brandywine quarry	do	do	Sylmar, 1 mile north of.
90	New Brandywine quarry.	do	do	Sylmar, near.
91	Old Brandywine quarry.	do	do	Sylmar, 1½ miles northwest of.
92	Old Keystone quarry	do	do	Sylmar, west of.
93	Rock Spring quarry	Maryland	Cecil	Conowingo, 3½ miles northeast of.
94	Bald Friar quarry	do	do	Conowingo, 1½ miles north of.
95	Zepp quarry	do	Howard	Marriottsville, ½ mile south of.
96	Warfield quarry	do	do	Adjoins Zepp quarry.
97	Old Warfield quarry	do	do	Across creek from new quarry.
98	Baker quarry	do	do	Marriottsville, ½ mile east of.
99	Gifford quarry	do	Baltimore	Granite, ½ mile south of.
100	Peach quarry	do	do	Granite, 1 mile south of.
101	Cavey quarry	do	Howard	Woodstock, ¾ mile south of.
102	Dietz quarry	do	Baltimore	Davis, ½ mile east of.
103	Alberton quarry	do	Howard	Alberton, ½ mile south of.
104	Ilchester quarry	do	Baltimore	Ilchester, near.
105	McNichols quarry	Virginia	Bedford	Lowry, 5 miles south of.
106	American rutile quarry	do	Nelson	Arrington, 8 miles northwest of.
107	Prospect quarry	do	Prince Edward	Prospect, near.
108	Old Schlegel quarry	do	Amelia	Jetersville, 1¼ miles northwest of.
109	Pegmatite dike	do	do	Jetersville, 2½ miles northeast of.
110	Rutherford mica mine	do	do	Amelia, 2 miles northeast of.
111, 112	Pinchback mica mines	do	do	Amelia, 2½ miles northeast of.
113	Champion mica mine	do	do	Amelia, 3 miles northeast of.
114, 115, 116	Hewletts mica mines	do	Hanover	Hewletts, 2 miles southeast of.
117	Garrett property	do	Henry	Ridgeway, 2 miles south of.
118	do	do	do	One-half mile east of No. 117.
119	do	do	do	One-half mile northwest of No. 117.
120	Ridgeway mica mine	do	do	Ridgeway, ¼ mile northwest of.
121	Blandford quarry	Massachusetts	Hampton	Blandford, ½ mile north of.

MAINE.

HANCOCK COUNTY.

EAST ORLAND. PEGMATITE DIKES.

Five miles northeast of Buckport, in the edge of East Orland village, Hancock County, Me., are a number of narrow pegmatite dikes (1). These dikes have withstood weathering better than the inclosing rocks and as a result protrude several feet above the land. The action of frost, however, has begun to disintegrate the feldspar and quartz particles along the lines of contact, so that low ridges of bowlders and coarse angular sand have formed, which are covered with rank growths of wild blackberries. The feldspar content of this pegmatite is a microcline with perthitic intergrowths of albite. In many places the pegmatite of these dikes contains tiny crystals of biotite so thoroughly distributed throughout the mass as to render its elimination impracticable. Other parts of the dike are reasonably free from minerals other than quartz and feldspar; this feldspar has a deformation range of 1,265° to 1,280° C.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

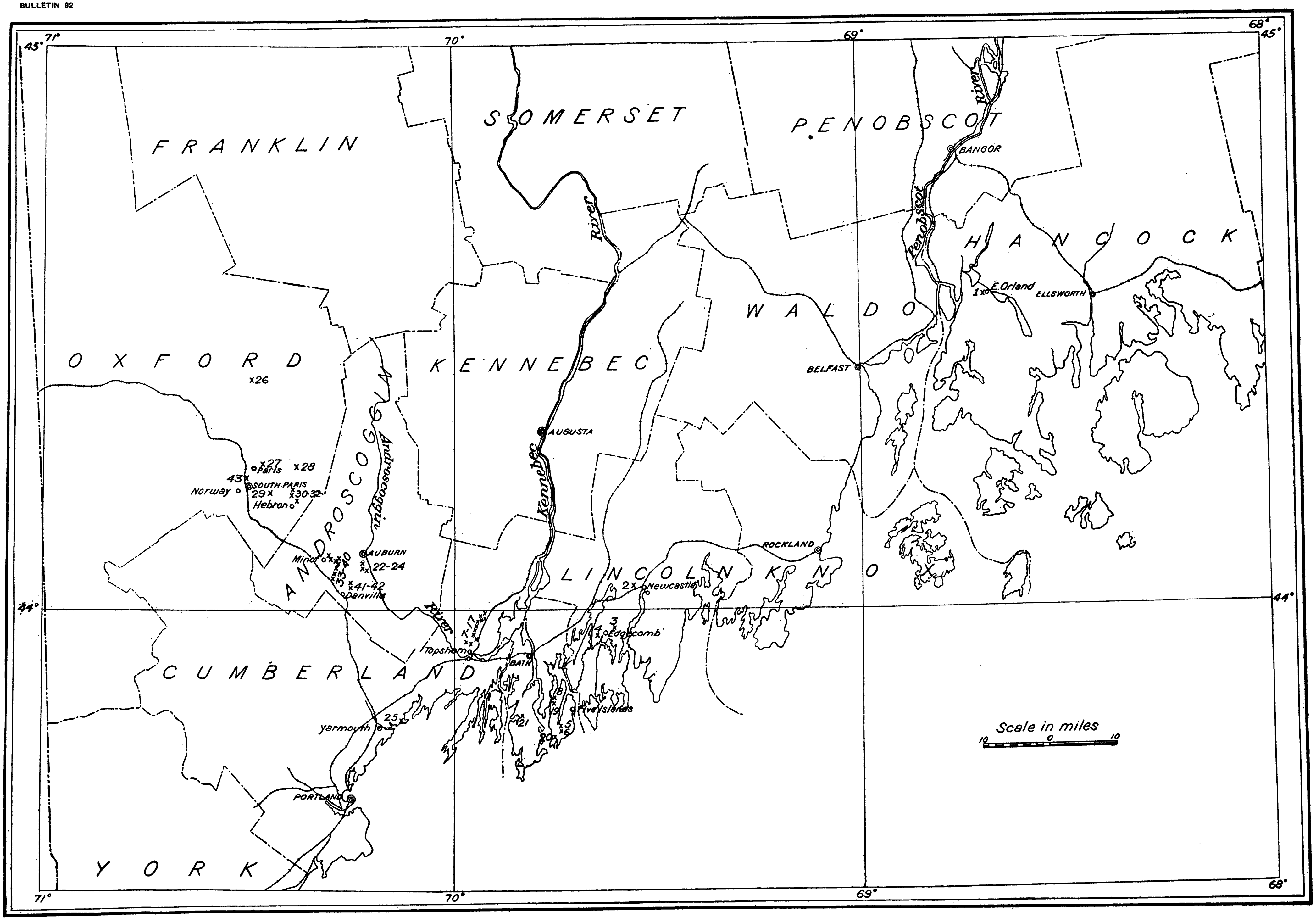
A standard porcelain mixture of this feldspar vitrifies at a temperature of 1,290° C. and shows a slight tendency to warp at 1,330° C. When fired at 1,330° it has a total shrinkage of 14.3 per cent, a cream tint by transmitted light, and a translucency of 0.660. The color is equal to that of the standard trial and is unaltered both under the raw-lead and the fritted glazes.

LINCOLN COUNTY.

NEW CASTLE. JOHN GLIDDEN PROPERTY.

The John Glidden property is 2 miles west of New Castle village. This deposit (2) is a dike that varies in width up to about 60 feet and is of varying quality as regards the occurrence of biotite and garnet. The garnet, however, is present in such quantity as to seriously injure the feldspar for pottery purposes. The dike strikes northeast, the dip varies from 80° West to 75° East. The west side of the dike is exposed, forming the face of a cliff 30 feet high, at the base of which a small stream runs south to tidewater, a distance of 1 mile. The Maine Central Railroad is 1½ miles south.

The developments consist of a few surface prospect pits which have been poorly placed and furnish little information as to the real structure of the dike. There is no overburden along an exposure of about 1,200 feet. The better parts of the dike where exposed were sampled and the average has the following chemical composition.



SKETCH MAP OF PART OF MAINE, SHOWING FELDSPAR DEPOSITS INVESTIGATED. FOR DESCRIPTION OF DEPOSITS SEE TABLE 2.

Composition of high-grade feldspar from Glidden property.

SiO_2	64.67
Al_2O_3	19.18
Fe_2O_3	0.20
CaO	0.99
MgO	Trace.
Na_2O	2.54
K_2O	12.76
	100.34

The analysis indicates a fairly fusible composition and the color when fused is above criticism as is the case with practically all of the Maine feldspars when properly cleaned of their associated ferromagnesium impurities. This feldspar deforms between 1,270° and 1,285° C., being slightly more fusible than Seger cone 8, it does not, however, become distorted in the early stages of fusion as might be expected from its calcium content. It fuses to an opaque white glass.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

A standard mixture of this feldspar vitrifies at 1,270° C. and shows slight warpage at 1,330° C. The color is equal to that of the standard trial. Fired at 1,330° the product has a total shrinkage of 14.6 per cent, a cream-white tint, and a translucency of 0.615. Under the raw-lead and fritted glazes the color is unaltered.

EDGECOMB. ABANDONED QUARRY.

There is an old abandoned quarry (3) at Edgecomb, 2½ miles from the New Castle Township line and 4½ miles southeast of Wiscasset.

This deposit [a] contains considerable impure pegmatite, due to the contamination of small biotite crystals, but also contains considerable commercial pegmatite, which is exposed in a well-defined part of the dike, 25 to 50 feet wide, and cleared of overburden for a distance of 100 feet. The same dike is exposed at various places of uncertain width for a distance of about 500 feet north. The dike is almost vertical. At the time of visiting an opening about 25 feet deep had been made for the recovery of mica of the muscovite variety, which occurs throughout the dike. The pegmatite contains small lenses of massive white quartz and some beryl in the parts rich in feldspar. The feldspar in the part of this dike not seriously contaminated with biotite mica was sampled and found to be of a very good quality but of a rather soft type, its deformation range being from 1,255° to 1,260° C. It fuses to an enamel-like glass and entirely loses its shape at 1,270° C.

[a] For a description of this deposit see Bastin, E. S., Economic geology of the feldspar deposits of the United States: U. S. Geol. Survey Bull. 420, 1910, pp. 27 and 28.

PROPERTIES IN THE STANDARD PORCELAIN MIXTURE.

The standard porcelain mixture of this feldspar vitrifies at 1,260° C. and shows warping at 1,290° C. Its color is hardly equal to that of the standard trial. Fired at 1,290° C. it has a cream tint by transmitted light and a translucency of 0.667, and a total shrinkage of 14.6 per cent. The color is unaltered under either raw-lead or fritted glaze.

EDGECOMB. HULL PROPERTY.

The Hull property (4) is on the east side of Sheepscot River, 4 miles south of Wiscasset, in the town of Edgecomb. This dike follows a ridge along the east side of the river, its height varying from sea level at high tide to 200 feet above sea level. The pegmatite does not seem to be so clean at the higher points but the material exposed there may be capping. Pegmatite of excellent quality is exposed at a number of places, but no development work has been done, and hence no estimate of quantity or uniformity can be made.

Samples of the clean pegmatite have a deformation range of 1,275° to 1,290° C. and fuse to a semitransparent mass free from color.

SAGADAHOC COUNTY.

GEORGETOWN. NOBLE AND SMITH PROSPECTS.

On Georgetown Peninsula, due east of the Golding quarry, is a dike of pegmatite, which may be traced over a considerable distance. Two openings (5 and 6) have been made, but no feldspar has been shipped. The feldspar exposed is microcline pegmatite with a small content of impurity, chiefly biotite.

Samples of the feldspar show a deformation range of 1,278° to 1,290° C. and fuse to a translucent glass free from tint.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

The standard porcelain mixture of this feldspar vitrifies at 1,280° and at 1,330° shows no warpage. Fired at 1,330° C. it has a total shrinkage of 14.3 per cent, a cream color by transmitted light, and a translucency of 0.640. The color is unaltered under the raw-lead and fritted glazes.

CATHANCE. ALFRED GRAVES QUARRY.

The Alfred Graves quarry (7) 2 miles north of Cathance station. At the time of inspection this property had been opened by a pit about 30 feet wide, 40 feet long, and 10 to 15 feet deep. A dike of varying width is exposed in places for at least 100 feet along the strike northwest and southeast of the pit. The dike reaches a maximum width of 70 feet in some places, but from surface indications its quality varies greatly. The overburden varies from one-half to 3 feet in thickness. Biotite occurs in considerable quantity in some parts of the dike, but in other parts is almost entirely absent. Beryl is present locally, but not in sufficient quantity to constitute a menace. About 500 tons of commercial pegmatite has been mined and shipped from this property, which shows indications of much more feldspar of pottery grade. The deposit lies nearly flat, and a band of coarse, impure granite, encountered at a depth of 10 to 15 feet, is reported as continuing through to the other side of the sill, but no prospect holes or other evidence is available to substantiate this claim.

Samples of this feldspar show a deformation range of 1,265° to 1,280° C. and fuse to a semitransparent mass free from tint.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

In the standard mixture the feldspar produces vitrification at 1,280° C. and at 1,330° C. shows no warpage. The color is the same as that of the standard trial. Fired at 1,330° C. the mixture has a total shrinkage of 14.3 per cent, is cream white by transmitted light, and has a translucency of 0.645. The color is unaltered under the raw-lead and fritted glazes.

CATHANCE. MAINE FELDSPAR QUARRY.

The Maine quarry (8) is 2 miles north of Cathance station, on property adjoining on the south of the Alfred Graves property. This deposit is probably a continuation of the dike opened at the Graves quarry but dips more than on the Graves property. This dike varies widely in its structure, and much material high in impurity must be handled in the removal of the merchantable pegmatite. The dike dips under a ridge and the increase in thickness of overburden which must be removed has prevented very deep quarrying. The pegmatite part of the dike averages about 12 feet in width. The feldspar has a deformation range of 1,265° to 1,280° C. and fuses to a semitransparent mass free from tint.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

In the standard porcelain mixture this feldspar produces vitrification at 1,280° and no warping is evident at 1,330° C. Fired at 1,330° C., the total shrinkage is 14.0 per cent, the color by transmitted light is cream white, and the translucency is 0.650. The color is unaltered under the raw-lead and fritted glazes.

CATHANCE. MAINE GRAPHIC GRANITE QUARRY.

This deposit (9) is 2½ miles northwest of Cathance and is part of the dike worked at the large Trenton quarry one-half mile north. At the time of visiting a face 60 feet wide and 60 feet high, worked in two benches, was exposed. The material exposed is a good grade of graphic granite, but contains both black and white mica, and all of it has to be cobbed or sorted before it is sent to the mill. The quality of the feldspar is practically the same as that of the potash feldspar being mined at the Trenton quarry, although the structure of the dike at this north exposure is more irregular and requires more careful mining than seems to have been necessary in working the older and larger opening.

A sample of the feldspar of this dike had a deformation range of 1,265° to 1,280° C. The fused product is a semitransparent mass free from tint.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

A standard mixture of the feldspar vitrifies at 1,270° and warps slightly at 1,330° C. The total shrinkage when fired at 1,330° is 14 per cent. The color is cream white, and the translucency is 0.635. The color is not altered by the application of either the raw-lead or the fritted glazes.

CATHANCE. TRENTON QUARRY.

The Trenton quarry [a] (10), 2 miles northwest of Cathance, is one of the oldest feldspar operations in Maine and represents the largest production in the New England States. The quarry, which is about three-fourths mile west of the highway, consists of a series of open cuts ranging from 15 to 60 feet in height of face exposed and in some places is 200 feet wide. This deposit has been worked out for a distance of 200 yards and the indications are that it continues for a considerable distance to the north, which is the direction of the strike of the dike. The deposit mined has consisted chiefly of a rich graphic granite and coarse pegmatite, with numerous lenses of sugar quartz and pure feldspar that in some places is potash feldspar and in other places soda feldspar. The soda feldspar is more or less broken by weathering, presenting a chalky appearance, but the potash feldspar seems to be still unweathered.

Samples of the potash feldspar were tested and showed a deformation range of 1,265° to 1,280° C. The color is an excellent white and the standard porcelain body in which this material is used shows a shrinkage of 14.6 per cent and a translucency of 0.667.

The soda feldspar deforms only at a very high temperature, owing to the fact that the weathering has removed some of the alkali, leaving a residue of semikaolinized material. This soda feldspar has never been used by the operating company as a commercial product, but a test of this material in porcelain bodies shows that it has a shrinkage of 13.4 per cent and a translucency of 0.620, which indicates that it would be valuable fluxing material for many purposes.

CATHANCE. OLD W. G. WILLIS QUARRY.

The W. G. Willis quarry [b] (11) is 1 mile west of Cathance. This property is south of the Trenton quarry and is apparently a continuation of this same dike or at least consists of stringers from this

[a] See Bastin, E. S., Economic geology of the feldspar deposits of the United States: U. S. Geol. Survey Bull. 420, 1910, pp. 38-39.

[b] Bastin, E. S., Op. cit., pp. 37-38.

dike. The mass is not so uniform as the main dike, but contains many large lenses of pure potash feldspar, the rest of it being an excellent grade of graphic granite. The opening of this quarry is in the center of a large flat plateau, and at the time of the writer's visit the quarry was filled with water to a considerable depth, making a satisfactory examination of this deposit impossible. The difficulty of operation has prevented this property being worked recently, but the feldspar mined was regarded as of excellent quality and was all bought and used by a local company.

The results of an analysis of a sample of this feldspar are as follows:

Results of analysis of potash feldspar from W. G. Willis quarry.

	Per cent.
Ignition loss	0.33
SiO_2	73.89
Al_2O_3	14.33
Fe_2O_3	.16
TiO_2	
CaO	Trace.
MgO	Trace.
BaO	
K_2O	9.2
Na_2O	2.14
Total	99.87

CATHANCE. OLD GOLDING QUARRY.

The old Golding quarry (12) is 1 mile west of Cathance station and adjoins the old W. G. Willis quarry on the south. This property was worked in former years when only the pure feldspar was removed, and hence much high-grade graphic granite is left and also many small dikes, which were formerly considered too small to justify quarrying. The structure and the strike of the deposit indicates that it is a continuation of the dike worked at the Maine, Trenton, and W. G. Willis quarries.

CATHANCE. NEW W. G. WILLIS QUARRY.

The new W. G. Willis quarry (13) is located on the same dike as the Trenton quarry, the old Golding quarry, and the old W. G. Willis quarry, and is due south from them. This quarry has the advantage of being near the southern slope of the hill, and hence the problem of drainage, which is the great handicap in the old W. G. Willis quarry, is not encountered here. The dike here, like all other exposures on this strike, varies widely but contains much pure feldspar and also much high-grade pegmatite and graphic granite. The muscovite, biotite, and beryl present in this part of the dike are all so coarsely crystalline that they can be easily eliminated by rough cobbing during mining. This quarry had not extended to any considerable depth at the time of inspection, but as the dike is nearly vertical it will doubtless produce much high-grade pottery feldspar. Samples of this feldspar have a deformation range of 1,275° to 1,290° C. and fuses to a translucent mass free from tint.

PROPERTIES IN STANDARD PORCELAIN MIXTURE

A standard mixture of this feldspar vitrifies at 1,280° C. and warps slightly at 1,330° C. Fired at 1,330° C., this mixture has a total shrinkage of 13.8 per cent, a cream-white tint, and a translucency of 0.660. Under the raw-lead and fritted glazes the color of the body is unaltered.

CATHANCE. OLD FISHER QUARRY.

The old Fisher feldspar quarry [a] (14) is directly south of the W. G. Willis quarry. This property has been reopened and a considerable quantity of excellent feldspar mined. The dike is similar to others in this district and consists of a graphic granite of medium to fine grain and many lenses of pure feldspar. Considerable beryl and muscovite is found in certain parts of this dike, but biotite seems to be present only in small quantity.

The graphic granite of this deposit was sampled and analyzed. The results of the analysis are as follows:

Composition of graphic granite from old Fisher quarry.

	Per cent.
SiO_2	74. 34
Al_2O_3	14. 45
Fe_2O_3	. 16
CaO	Trace.
MgO	Trace.
Na_2O	2. 00
K_2O	8. 63
	99. 56

The composition of the feldspar content of the graphic granite was as follows:

Composition of feldspar content of graphic granite.

	Per cent.
SiO_2	65. 07
Al_2O_3	19. 39
CaO	Trace.
MgO	Trace.
Fe_2O_3	. 10
K_2O	12. 58
Na_2O	2. 52
	99. 66

The pure feldspar has a deformation range of 1,275° to 1,290° C. and fuses to a semitransparent mass free from tint.

[a] See Bastin, E. S., Op. cit., pp. 36–37.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

The standard mixture of this feldspar vitrifies at 1,280° and warps slightly at 1,330° C. The color is equal to that of the standard trial. Fired at 1,330° C., the mass has a total shrinkage of 13.8 per cent, a cream-white tint, and a translucency of 0.683. The color is unaltered under the raw-lead and fritted glazes.

TOPSHAM. MAINE FELDSPAR CO. DEPOSIT.

The Maine feldspar deposit (15) is 2 miles east of Topsham. This property, which was opened during the summer of 1912, lies along a ridge running northeast. The dike varies from 80 to 100 feet in width and is exposed for a distance of about 750 feet. The deposit dips about 70° west, but is so folded that the continuation of this dip with depth is uncertain. The dike material consists of a graphic granite or pegmatite of varying coarseness and contains numerous lenses of material very rich in biotite, which is in the form of large lath-like crystals, having a maximum length of 1½ feet and a width of 3 inches. At the time of visiting, the dike had only been exposed to a depth of about 10 feet along the south face, but at the north end of the property an exposure about 30 feet high had been made which showed a reasonably uniform grade of graphic granite of a buff color.

This material was carefully sampled and was found on testing to be a good average feldspar, having a deformation range of 1,270° C. to 1,285° C. Samples of the pure feldspar lens in this dike were tested and found to have a deformation range of 1,260° C. to 1,270° C., which indicates that this pure feldspar is much more fusible than the graphic granite and should be valuable for softening the other material, which is naturally more or less refractory owing to the quartz content of the graphic granite.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

The graphic granite, when made into a standard porcelain body, shows a shrinkage of 14 per cent, a cream-white tint, and a translucency of 0.635. The pure feldspar, when made into a standard porcelain body, shows a shrinkage of 13.4 per cent and a cream translucency of 0.707. Under the raw lead and fritted glazes the color is unaltered.

TOPSHAM. MOUNT ARARAT QUARRIES.

About 1 mile north of Topsham village, on Mount Ararat, are numerous dikes of pegmatite, which have been worked at different times for feldspar.[a] None of these dikes are large but the structure is so folded that most of the work has consisted of removing the high-grade pegmatite exposed on the surface.

At the time of visiting there was a large, shallow pit about 150 feet long and 30 feet wide on the north slope of the hill and the deposit had apparently been worked out.

[a] For a description of these deposits see Bastin, E. S., Economic geology of the feldspar deposits of the United States: U. S. Geol. Survey Bull. 420, 1910, pp. 34-36.

A quarry (16) has been opened on the west slope of Mount Ararat and follows the slope for a distance of about 50 feet. The dike structure here is much folded, and many bands of gneiss are inclosed in the deposit, so that only about 40 per cent of the dike material is pegmatite. This deposit produced only a small amount of merchantable feldspar and has been abandoned as a source of high-grade material, being used recently as a quarry for the production of road material, which is crushed near the quarry and used on the neighboring highways.

On the south slope of the hill a quarry (17) about 30 feet long by 20 feet wide has been opened. This deposit is a mixture of microcline and albite pegmatite, and contains very little biotite and garnet, which is generally very prevalent in the pegmatite of this district. This quarry has been worked to a depth of about 20 feet and the walls and floor indicate that good pegmatite still remains in this pit, although the deposit is much folded. The wall rock, which is a schist, does not intrude into the dike at this point. Very few masses of pure feldspar are exposed but the pegmatite, where not contaminated by iron-bearing minerals, is of a good pottery grade.

This feldspar deforms at 1,260° C. to 1,270° C., and fuses to an enamel-like semiopaque pure white mass.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

The standard porcelain mixture of this feldspar vitrifies at 1,270° C., and at 1,330° C., slight warpage is evident. The color is similar to that of the standard trial. After firing at 1,330° C. the total shrinkage is 13.8 per cent, and the translucency is 0.670 and the color cream white.

BATH. DAUPHIN PROPERTY.

On a hill one-half mile west of High Street, Bath, are two ledges of pegmatite, which are apparently of a quality to produce commercial pottery feldspar. The ledges are dikes which project about 25 feet above the ground, and on their exposed surfaces show a fair grade of pegmatite with many small masses of pure feldspar of a buff color. No prospecting has been done and the surface material is so badly stained from the thin overburden of soil that no reliable report was possible on this deposit.

TOPSHAM. NOYES PROPERTY.

In the west end of the village of Topsham, on the main street and 1 mile west of the post office, is a pegmatite dike. The surface pegmatite is of good quality but at the time of visiting no development had been attempted and little could be determined from the exposure, which was about 30 by 125 feet and about 50 feet from the highway. The feldspar is buff colored where exposed, and the pegmatite seems to be very low in quartz content. Biotite, garnets, and magnetite are noted, but are not abundant and are confined to limited areas. Massive quartz and feldspar are also present. This dike is in the center of a level area, and a brook which runs along the east wall of the dike would have to be diverted into a new and lower channel or pumping resorted to if the deposit were to be mined.

RIGGSVILLE. MASON DEPOSIT.

The Mason property (18) is on Georgetown Peninsula, near the town of Riggsville. Deposits of feldspar are exposed over a large area and as ledges above Back River, which is tidewater. The dikes strike in all directions from northeast to southeast, and the dip varies from 45° to 90°. The deposits have been developed only by a few poorly placed shots, and little real information regarding the structure of the dikes below the surface is available. The presence of considerable garnet was noted, and lenses of pure feldspar at frequent intervals. These lenses were sampled and found to be of fair quality.

The feldspar present is a microcline with minute intergrowths of albite. It has a deformation range of 1,275° to 1,290° C. and fuses to a semitransparent mass free from tint.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

The standard mixture of this feldspar vitrifies at 1,280° C. and warps slightly at 1,330° C. The color is equal to that of the standard trial. Fired at 1,330° C. it has a cream-white tint, a translucency of 0.643, and a total shrinkage of 13.9 per cent. Under the raw-lead and fritted glazes no change in color occurs.

RIGGSVILLE. NOBLE DEPOSIT.

The Noble deposit (19) is on Georgetown Peninsula, due southeast of the Mason deposit, and consists of at least four stringers, which strike northwest to southeast across a ridge. The material of the dikes is of varying quality, but seems to consist of a fair quality of feldspar in some places, grading into a fine-grained pegmatite in other places. The lack of any but surface exposures prevented a more thorough investigation of this deposit. Where pure masses of feldspar occur it resembles the pure feldspar of the Mason deposit and has the same range of deformation.

GEORGETOWN. GOLDING QUARRY.

The Golding quarry (20) is on Georgetown Peninsula. The deposit has been described by Bastin.[a]

At the time the writer visited this property the last opening and the one being operated consisted of an open cut about 50 feet wide and directly below the original opening. The new cut is made from the face of the hill and thus affords natural drainage, obviating the

[a] Bastin, E. S., Economic geology of the feldspar deposits of the United States: U. S. Geol. Survey Bull. 420, 1910, pp. 31, 32, and 33.

necessity of siphoning, which was required in the old opening. A lens of pure feldspar about 20 by 50 feet in size lies directly to the east of this cut. The greater part of this lens had been removed and utilized to raise the feldspar content of the output from the main deposit, which consists chiefly of a pegmatite or graphic granite. This graphic granite was sampled and analyzed. The results of the analysis are as follows:

Composition of graphic granite from Golding quarry.

	Per cent.
SiO_2	74.53
Al_2O_3	14.26
Fe_2O_3	.16
CaO	Trace.
MgO	Trace.
Na_2O	2.25
K_2O	8.55
	99.75
Combined H_2O	.30

This deposit contains very little mica, either in the form of muscovite or biotite, the chief impurity being sharply defined crystals of black tourmaline (schorl), which is separated by cobbing from the rest of the dike material. The product as marketed is of good quality, but being graphic granite necessarily contains some free quartz.

At this quarry the face was mined in benches 2½ to 3 feet wide and 5 feet high. The holes are made with steam drills and loaded with 40 per cent dynamite, the shots being fired at noon and night after the workmen have left the quarry. The loosened material is removed from the quarry in tramcars. which run on a track and are drawn by horses.

The quarry is situated directly on tidewater and the feldspar is loaded into scows and conveyed to Bath, Me., and there reloaded for shipment to the western pottery centers, or is shipped directly from the quarry wharf by barge to Trenton, N. J.

This material begins to deform at about 1,270° C. and is completely deformed at 1,285° C., but at 1,290° shows no evidence of becoming a fluid glass. The fused feldspar is free from tint and is semitransparent.

PROPERTIES IN THE STANDARD PORCELAIN MIXTURE.

The standard porcelain mixture made with this feldspar vitrifies at 1,280° C., and at 1,330° C. shows no warpage. The color is equal to that of the standard trial. When fired at 1,330° C. the total shrinkage is 14 per cent, the color cream white, and the translucency 0.670. Under the raw-lead and fritted glazes the color is unaltered.

PHIPPSBURG. JOSEPH B. PERRY PROPERTY.

The Joseph B. Perry property (21) is adjacent to and 50 to 80 feet above tidewater at Phippsburg Basin, town of Phippsburg. This feldspar deposit is a well-defined dike, which varies in width from 6 to 15 feet and strikes northwest to southeast. The deposit is almost vertical and has been opened to a depth of 10 to 20 feet. The original work was done on this property in 1878 and about 350 tons of feldspar were shipped. Toward the west end this dike contains intrusive lenses of pure quartz and toward the east end the pegmatite, of which the dike principally consists, is replaced by pure feldspar lenses of considerable size. Large crystals of muscovite occur along the walls, but this muscovite is mostly of grinding quality only. The lenses of pure feldspar appear to be of very uniform quality and were sampled, an average of the samples showing the following chemical composition:

Composition of pure feldspar from Perry property.

	Per cent.
SiO_2	64.90
Al_2O_3	19.75
Fe_2O_3	.12
CaO	None.
MgO	Trace.
Na_2O	2.68
K_2O	12.04
	99.49
Combined H_2O	.25

This feldspar deforms between 1,265° and 1,280° C. and has an excellent color. When fused at 1,290° the product is a semitransparent glass.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

The standard mixture of the feldspar vitrifies at 1,270° C., and at 1,330° C. shows no warpage. The color is equal to that of the standard trial. Fired at 1,330° C. the feldspar is cream white, the translucency is 0.637, and the total shrinkage is 14.7 per cent. The color is unaltered under either the raw-lead or the fritted glaze.

CUMBERLAND COUNTY.

SOUTH FREEPORT. STAPLE POINT DEPOSIT.

There is a feldspar deposit (25) on Staple Point, a short peninsula on the coast just west of South Freeport, Cumberland County, Me. Dikes 6 to 15 feet wide containing much pure feldspar extend along the ridge of this peninsula for a distance of 700 or 800 feet in a westerly direction. The land lies from 30 to 50 feet above tidewater, but many exposures of promising quality are noted below tide level. Along the coast at this point the water is not deep enough for schooners to enter, but scows could be loaded directly from the deposit or the material could be hauled by wagon to South Freeport and from there shipped by rail to any desired point.

The surface material consists of both feldspar and pegmatite; no openings have been made of sufficient size to indicate the quality of the lower part of the deposit. There is no overburden except a few inches of soil or loam, and the deposit could easily be thoroughly tested by a few well-placed holes. If the inconvenience of tidewater operations can be overcome there is every evidence that this deposit should produce some excellent feldspar.

The feldspar of this deposit was carefully sampled and tested, and the results show that the deforming temperature lies between 1,255° and 1,270° C.

PROPERTIES IN THE STANDARD PORCELAIN MIXTURE.

Made into a standard porcelain body the feldspar shows a translucency of 0.663 and has a shrinkage of 13.4 per cent. The color when fused is an excellent white.

AUBURN. CHARLES SAWYER DEPOSIT.

The Charles Sawyer deposit (41), at Rumford Junction, 4 miles west of Auburn, is a dike consisting of a number of separate bands that vary from 2 to 20 feet in width and differ widely in structure. A highway lies between the railroad and the exposure, which is on the east slope of a hill and rises to a maximum height of 130 feet above the railroad. On the lower parts of this slope a number of lenses, showing a fair quality of pegmatite and numerous lenses of pure feldspar, are well exposed. The banded part of this dike which is exposed at higher levels has a more granitelike structure, and where the micas and garnet occur as impurities is too fine grained to be cleaned.

The better parts of this deposit were sampled and found to have an excellent color and a deformation range of 1,270° to 1,285° C.

The feldspar fuses to a semitransparent mass free from tint.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

The standard mixture of this feldspar vitrifies at 1,280° C. and warps slightly at 1,330° C. Its color is equal to that of the standard trial. Fired at 1,330° C. the total shrinkage is 14.1 per cent, the translucency is 0.667, and the color by transmitted light is cream white. The color is not altered by the raw lead and fritted glazes.

AUBURN. DOW PROPERTY.

The Dow property (42) is at Rumford Junction, 4 miles west of Auburn, on an elevation due west of the Sawyer property. A dike of pegmatite of variable quality is exposed on a ridge running north and south. At the time of visiting no development work had been done, but numerous lenses of pure feldspar are exposed and masses of pegmatite free from impurity are numerous also. The major part of the dike, which can be traced for about 300 yards, is a fine-grained pegmatite with much biotite and some small garnets exposed on the surfaces. This property would justify more thorough prospecting.

OXFORD COUNTY.

DIXFIELD. OLD KNOX QUARRY.

The old Knox quarry (26) is 3½ miles southwest of Dixfield, where a large dike of pegmatite of varying quality outcrops on the southwest face of a steep cliff. It has been worked at various times for mica, of which only a limited amount of marketable material has been obtained. The exposure is from 20 to 40 feet wide. Along the abrupt slope of the hill occasional lenses of pure feldspar may be observed, but the fact that biotite is distributed throughout most of the exposed face indicates that this material would require hand sorting to make it marketable feldspar. Also small garnets are scattered through a considerable part of the exposed face and would tend to reduce the commercial value of the product somewhat, although they probably would not cause it to be rejected.

Samples of the pegmatite and pure feldspar were taken in the proportions in which they are estimated to occur and these samples were tested with the following results: Deformation range, from 1,270° to 1,285° C.; color, good; shrinkage of standard porcelain body, 14.2 per cent; translucency, 0.597.

SOUTH PARIS. MOUNT MICA DEPOSITS.

There are deposits of feldspar (27) on the crest of Mount Mica, 5 miles northeast of South Paris. Mount Mica consists of a ridge with one pronounced knoll, which appears to be the center of an area very rich in gem materials. The dike has a general east and west trend and dips slightly southwest. The structure of this dike is exceedingly variable and does not seem to be banded, but is rather a mass of associated lenses of widely varying composition. Numerous lenses of massive feldspar are encountered and also many lenses of both graphic and irregular pegmatite. Muscovite and black tourmaline are common, but there is very little garnet evident. Lithia mica (lepidolite) is scattered throughout the deposit and its presence is considered to indicate a gem pocket. Both the pegmatite and the massive feldspar are of sufficient quality to justify their use as ceramic materials, the distance from a railroad being the chief drawback to their use. Hand sorting would be necessary to insure the elimination of the undesirable associated material, but would undoubtedly be profitable.

Samples of the feldspar from this deposit show a deformation temperature of 1,260° to 1,265° C., and 10° more converts the material into a glass of enamel-like opacity but lacking the complete fusion indicated in most high-soda feldspars.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

In the standard porcelain mixture the product has a shrinkage of 14.4 per cent and a translucency of 0.647. The translucency is high for a porcelain containing the proportion of soda feldspar which the deformation action seems to indicate.

OWLS HEAD. BUCKFIELD DISTRICT.

The Buckfield district (28) is north of Owls Head and east of Streaked Mountains. It consists of a low ridge with numerous small dikes of pegmatite, all having an east and west trend. Some are quite free from impurities and others are so impure as to be valueless. The impure ones, contain, however, practically every rare gem and mineral found in Maine. The purer deposits of feldspar and pegmatite have not been opened as prospecting through this district has been confined heretofore to searches for gem minerals, and the dikes containing pure feldspar are in most cases exposed only by the removal of the overburden. The feldspar and pegmatite seem to be uniform in quality and in several places extend continuously for about 100 feet. The fact that no openings had been made in this clean rock prevented a satisfactory sample being taken by the writer, but the indications point to the presence of good commercial material in this district.

SOUTH PARIS. HOOKER RIDGE.

On Hooker Ridge, 1½ miles east of South Paris, a pegmatite dike (29) is exposed on the west slope of an abrupt hill and has a general strike north and south which permits its being easily quarried. At the time of visiting the exposure was about 250 feet long and 40 feet high. The bands adjoining the hanging wall, which is on the east, are full of biotite and can not be sufficiently refined for ceramic uses. The west half of the dike, which varies in thickness from 10 to 30 feet, is a mixture of massive feldspar and pegmatite with the impurities in isolated lenses, which would permit their removal by hand cobbing and sorting. The impurities in this part of the dike consist chiefly of black tourmaline and muscovite, also numerous lenses of a fine quality of rose quartz are encountered. About 25 to 30 per cent of this dike could be made marketable material.

The marketable material was carefully sampled and found to have a deformation range of 1,275° to 1,290° C. When fused it becomes semitransparent and is free from tint.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

In the standard porcelain mixture this feldspar vitrifies at 1,280°, and at 1,330° C. shows no warpage. The color is equal to that of the standard trial. Fired at 1,330° C. the total shrinkage is 13.8 per cent, the translucency is 0.657, and the color cream-white.

HEBRON. NO. 4 HILL QUARRY.

The No. 4 Hill quarry (30) is on the south slope of No. 4 Hill in the town of Hebron.[a]

This quarry is opened in a dike of coarsely crystalline pegmatite, many masses of pure feldspar being exposed both on the surface of the dike and on the walls and floor of the quarry. The feldspar constituent of the pegmatite is chiefly microcline, a small amount of albite occurring as clevelandite in small pockets scattered through the dike. Biotite is almost entirely absent, the chief iron-bearing mineral in the pegmatite being black tourmaline. This mineral does not occur in isolated masses as is the case in most dikes where it is found, but is scattered as small crystals throughout the extent of the dike so far as exposed. Careful cobbing will be required to eliminate it from the feldspar. The lenses of feldspar free from quartz are also comparatively free from tourmaline, hence this part of the dike may be made use of. The proportion of the deposit which would be marketable is not great enough to make quarrying very profitable. Muscovite (white mica) is scattered in "books" through the dike, but is ruled, and hence would not be valuable except for grinding. Samples of the pure feldspar show a deformation range of 1,270° to 1,290° C. and fuse to an almost transparent glass.

PROPERTIES IN THE STANDARD PORCELAIN MIXTURE.

In the standard porcelain mixture this feldspar vitrifies at 1,280° C. and at 1,330° C. shows no warpage. The color is equal to that of the standard trial.

Fired at 1,330° C. the total shrinkage is 14.2 per cent and the translucency is 0.647 and the color cream-white. The color is not altered by either raw-lead or fritted glaze.

HEBRON. HIBBS QUARRY.

The Hibbs quarry[b] (31) is 1 mile north of Hebron Academy in the town of Hebron and 3 miles west of East Hebron Station. This deposit is situated in a level tract in the heart of an elevated area of considerable extent and a stream passes directly over the deposit, exposing it in many places.

The dike is distinctly banded, several of the bands being practically pure feldspar and others high-grade pegmatite. The dike strikes almost north and south and dips 45° west. Along the hanging wall large blocks of excellent muscovite were exposed at the surface or in the bottom of shallow shot holes which had been drilled there. A width of 12 to 15 feet of this dike could be profitably quarried for its feldspar and should yield an excellent material, judging from the

[a] See Bastin, E. S., Economic geology of the feldspar deposits of the United States: U. S. Geol. Survey Bull. 420, 1910, pp. 29-30.

[b] See Bastin, E. S., Op. cit., pp. 28-29.

results of the tests and analysis. The feldspar had the following composition:

Composition of feldspar from Hibbs quarry.

	Per cent.
SiO_2	65.48
Al_2O_3	19.39
Fe_2O_3	.08
CaO	None.
MgO	Trace.
Na_2O	2.85
K_2O	11.51
	99.31

The feldspar has a deformation range of 1,260° to 1,280° C. and fuses to a semitransparent glass free from tint.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

A standard mixture of this feldspar vitrifies at 1,280° C. and warps slightly at 1,330° C.; the color is equal to that of the standard trial. The total shrinkage at 1,330° C. is 15 per cent, the translucency is 0.680 and the color is cream-white.

PARIS HILL. MOUNT RUBELLITE DEPOSIT.

The Mount Rubellite deposit (32) is north of Paris Hill post office. This deposit is not extensive and resembles in many ways the Mount Mica deposit. The dike contains practically all the minerals found at Mount Mica, the major part of it consisting of an irregular mass of feldspar and coarse pegmatite. This was sampled and tested and found to have a deformation range of 1,265° to 1,280° C. In the standard porcelain body the material showed a shrinkage of 14.2 per cent and a translucency of 0.675.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

This feldspar in the standard porcelain mixture vitrifies at 1,280° and does not warp at 1,330° C. The color is similar to that of the standard trial. Fired at 1,330° C. the total shrinkage is 14 per cent, the translucency is 0.660, and the color by transmitted light is cream white. The application of raw lead and fritted glazes does not affect the color of the porcelain.

NORWAY. STEVENS LEDGE.

Stevens Ledge (43) is 2 miles northeast of Norway, and consists of a dike exposed for a considerable distance across a ridge. Another dike, or a stringer of the same dike, of less width but greater purity, adjoins this chief deposit on the west. The general strike of both dikes is north and south and the dip is practically vertical. The larger dike forms a ridge, owing to the weathering away of the rock in which it is intruded, about 15 feet high. The pegmatite contains muscovite and biotite in small quantity, but disseminated throughout the mass, and also some small garnets. The smaller dike to the west contains very coarse pegmatite and massive feldspar, and has been opened to a depth of about 10 feet. Its chief impurity is black tourmaline, which is present only in coarse aggregate. A short distance to the west of these two dikes, ledges of quartz about 6 feet wide outcrop on the hill slope, which indicates the occurrence of other dikes striking at right angles to the two chief pegmatite deposits.

The feldspar from the smaller dike was sampled and analyzed, the composition being as follows:

Composition of feldspar from Stevens Ledge.

	Per cent.
SiO_2	64.97
Al_2O_3	19.48
Fe_2O_3	.04
CaO	None.
MgO	Trace.
Na_2O	2.56
K_2O	11.76
	98.81
Combined H_2O	.125

This feldspar had a deformation range of 1,270° to 1,285° C. In the standard porcelain mixture it has a shrinkage of 14 per cent and a translucency of 0.630.

ANDROSCOGGIN COUNTY.

AUBURN. PEGMATITE DIKE.

In the Hillcrest section of South Auburn a feldspar deposit (22, 23, 24) extends along a range of hills 1½ miles south of Auburn, between the old Danville road and the Mill road, and outcrops on a number of properties. The dike has an irregular formation and has a general north and south trend, but gives off many stringers at widely different angles. Trap-rock dikes cut this pegmatite dike at many points. The chief impurities associated with the pegmatite are black tourmaline, small garnets, and mica. The major part of the dike consists of a coarse pegmatite which could be rendered commercially pure by reasonable care in hand sorting. No attempt has been made to develop this deposit, and the dike structure where exposed by the few openings made varied so widely that the possibilities of the deposit could not be estimated. The better part of the dike was sampled. The results of the chemical analysis of this sample are as follows.

Composition of better grade of feldspar.

	Per cent.
SiO_2	67.81
Al_2O_3	18.55
Fe_2O_3	.08
CaO	.21
MgO	.07
Na_2O	4.27
K_2O	9.32
	100.31

This material has a deformation range of 1,270° to 1,285° C. and has an excellent color.

PROPERTIES IN THE STANDARD PORCELAIN MIXTURE.

The standard mixture of this feldspar vitrifies at 1,280° C. and at 1,330° C. shows no warping. The color is good, but hardly equal to that of the standard trial, which may be due to the fact that the samples were surface stained. Fired at 1,330° C. the standard mixture has a total shrinkage of 15 per cent, a translucency of 0.637, and is cream-white.

MOUNT APATITE. PULSOPHER DEPOSIT.

The Pulsopher deposit (33) is on the west slope of Mount Apatite and about one-fourth mile northwest of the other workings on that slope. The deposit consists of a large lens of soda feldspar, which has been worked exclusively for gem materials. This feldspar has never been tested for ceramic uses and the extent of the workings does not indicate that the amount of material here is very great, but the quality and color are both excellent and are characteristic of the best soda feldspar. An average of the samples taken had the following chemical composition:

Composition of soda feldspar from Pulsopher deposit.

	Per cent.
SiO_2	66.36
Al_2O_3	21.35
Fe_2O_3	0.12
CaO	1.10
MgO	0.21
Na_2O	9.74
K_2O	0.73
	99.61
Combined H_2O	.16

This feldspar has a deformation range of 1,265° to 1,270° C. and at 1,275° fuses to an opaque glass.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

This feldspar produces vitrification at 1,270° but the porcelain has a dull surface and lacks the metallic ring characteristic of porcelain of the potash variety. The color is excellent, but the surface texture is so different that it can not be compared with the standard trial. The total shrinkage when fired at 1,330° C. is 12.8 per cent, the translucency is 0.570, and the color is cream. Under the raw-lead and fritted glazes the color is not altered.

MOUNT APATITE. TOWNE QUARRY.

On the west slope of Mount Apatite and 100 yards below the highway is a dike (34) from which several hundred tons of good pottery feldspar has been obtained. The dike has a northeast strike and is almost vertical. It averages about 25 feet wide and has been opened to a depth of about 20 feet. The dike has an extremely irregular structure and contains a number of lenses of almost pure feldspar which is a microcline with intergrowths of albite. This feldspar has a deformation range of 1,270° to 1,285° and fuses to a semitransparent glass free from tint.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

The standard mixture of this feldspar vitrifies at 1,280° C. and at 1,330° C. shows a slight tendency to warp. The color is equal to that of the standard trial. Fired at 1,330° C. the total shrinkage is 13.8 per cent, the translucency is 0.640, and the color by transmitted light is a cream-white. Under the raw-lead and fritted glazes the color of the porcelain is unchanged.

AUBURN. GREENLAW QUARRY.

The Greenlaw Quarry (35) was opened several years ago on top of Mount Apatite, 3 miles west of Auburn.

The deposit consists of an irregular lens of graphic granite, of moderate coarseness and fair uniformity, similar to the other deposits on Mount Apatite. This property has been worked at various times for gem material and at present (1914) the feldspar production is of secondary importance, although the operator finds no difficulty in disposing of the quarried material, the output being used at the feldspar mill at Littlefield Station, 3½ miles southwest of Auburn and 2 miles south from this deposit.

This material was sampled and found to have a deformation range between 1,270° and 1,280° C. Heating above 1,280° caused it to quickly flow, which indicates that the alkali content is largely soda. The results of a chemical analysis of this material were as follows:

Composition of graphic granite from Greenlaw quarry.

	Per cent.
SiO_2	71.55
Al_2O_3	18.11
Fe_2O_3	0.16
CaO	0.46
MgO	Trace.
Na_2O	8.72
K_2O	0.64
	99.64
Combined H_2O	.75

The color of this material is a faultless white.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

In the standard mixture the feldspar vitrifies at 1,280° C. and at 1,330° C. warps slightly. The color is a matt white and when struck the porcelain has the characteristic ring which is peculiar to soda feldspar porcelains.

Fired at 1,330° C. the total shrinkage is 14.1 per cent, the translucency is 0.647, and the color is cream. The color is not altered by application of either raw-lead or fritted glaze.

AUBURN. MAINE QUARRIES.

There are a series of more or less connected pits (36, 37) on the crest of Mount Apatite, 3 miles west of Auburn.[a] None of the workings are deep, the maximum depth being about 25 feet. This is due to the fact that the dike consists of irregular folded bands, the valuable material being chiefly in pockets or lenses in very low-grade material. The dike or dikes on the summit of Mount Apatite were first worked for the gem minerals which are occasionally found associated with pegmatite. In the search for gems many small pits were opened, and where merchantable feldspar was encountered this was later removed and if a good grade of pegmatite was indicated the quarrying was continued until low-grade material was encountered. Prospecting has not been systematic and doubtless much valuable pegmatite and feldspar still remain on this tract.

The pegmatite varies greatly, consisting of pure lenses of feldspar and massive quartz in some places and fine-grained graphic granite in others. All the associate minerals in pegmatite are encountered on this property. Both muscovite and biotite mica are common but the muscovite generally is in book form and is seldom scattered throughout the pegmatite. The biotite sometimes occurs as lath-shaped crystals but is generally found in limited areas and can be eliminated if care is exercised in sorting the quarried material. Garnets and black tourmaline are found in limited areas but are not abundant in the pegmatite rich in feldspar. Beryl is found in the feldspar lenses but generally has a pronounced blue color and can be easily detected and removed. Apatite and gem tourmaline occur in pockets of albite and are scattered throughout the dikes.

The feldspar constituent of these dikes is a buff to cream microcline with intergrowths of albite. Bastin [b] gives the results of an analysis by the United States Geological Survey as follows:

[a] For a description of these deposits see Bastin, E. S., Economic geology of the feldspar deposits of the United States: U. S. Geol. Survey Bull. 420, 1910, pp. 24-25.

[b] Bastin, E. S., Op. cit., p. 24.

Composition of feldspar from Maine quarry.

	Per cent.
H_2O	0.48
SiO_2	65.73
Al_2O_3	[a] 19.28
CaO	.22
MgO	.00
K_2O	10.26
Na_2O	4.08
	100.05

This feldspar has a deformation range of 1,265° C. to 1,280° C., and fuses to a semitransparent mass of excellent color.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

A standard mixture of this feldspar vitrifies at 1,280° C., and at 1,330° C. shows slight warping. Its color is equal to that of the standard trial. Fired at 1,330° C. the total shrinkage is 13.8 per cent and the translucency is 0.650, the color being cream white. The raw-lead and fritted glazes do not alter the color of the porcelain.

AUBURN. PEGMATITE DEPOSIT.

There is a feldspar deposit [b] (38) on the south slope of Mount Apatite, 3½ miles west of Auburn, which consists of an irregular lens of considerable extent and a number of stringers. The material is chiefly coarse pegmatite with a varying content of impurities, which are garnet, tourmaline, muscovite, biotite, and beryl. A great many other gem minerals have been found in this immediate neighborhood and this dike or lens has been worked irregularly in the hope of locating a pocket of valuable minerals. The pegmatite constituting the main part of the mass can be cleaned by hand sorting and a considerable amount of high grade material obtained for ceramic use. The exposed parts were sampled. This material was found to have a deformation temperature of 1,270° C. to 1,285° C. and an excellent color.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

In the standard mixture the feldspar vitrifies at 1,280° C. and at 1,330° C. no warping is noted. The color is equal to that of the standard trial. Fired at 1,330° C. the total shrinkage is 14 per cent, the translucency is 0.670, and the color by transmitted light is cream white.

AUBURN. HAVEY QUARRY.

The Havey feldspar quarry (39), about 3½ miles west of Auburn, has been opened only a few years, and adjoins the Berry quarry, being on the same dike. The material appears the same, but the

[a] Includes trace of iron and any TiO_2 and P_2O_3 that may be present.
[b] Bastin, E. S., op. cit., pp. 25–26.

structure of the dike is even more lenticular than the Berry operations indicate. The soda feldspar present is almost entirely cleve-landite and the quarrying is necessarily carried on with special care on account of the possible presence of gem material in all parts of the quarry. The remarkable running out of the pegmatite at a depth of about 20 feet, which was observed in both quarries, is apparently due to an abrupt folding of the dike, which above the fold seems to be almost vertical but below it is very irregular wherever exposed.

The feldspar deforms at 1,270° C. to 1,285° C., and fuses to a semitransparent mass free from tint.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

This feldspar produces vitrification at 1,280° C., and at 1,330° C. no warping is apparent. The color is similar to that of the standard trial. Fired at 1,330° C. the total shrinkage is 14.2 per cent and the translucency is 0.665. The color is not affected by applying either the raw-lead or fritted glaze.

AUBURN. BERRY QUARRY.

The Berry feldspar quarry (40) is located on the southwest bank of the Little Androscoggin River, 1 mile southwest of Mount Apatite and 3½ miles west of Auburn.

The deposit [a] consists of an exposed lens in a dike trending north and south and containing a number of large lenses of excellent feldspar and numerous smaller lenses of gem-bearing material. This property has been worked for both feldspar and gem minerals and has been very productive. Owing to the sudden change from pegmatite to impure granitelike material, mining has only been carried to a depth of about 20 feet. In the vicinity of the gem-bearing deposits are lenses of the soda feldspar clevelandite, with which are associated lenses of massive albite. This material has a comparatively high deformation temperature, but has the short deformation characteristic of soda feldspar. The quantity of this material, however, is too uncertain to justify extensive investigations. The potash feldspar, however, which constitutes the major part of this deposit, is of a very uniform quality. It has a deformation temperature of 1,270° to 1,285° C. and an excellent color.

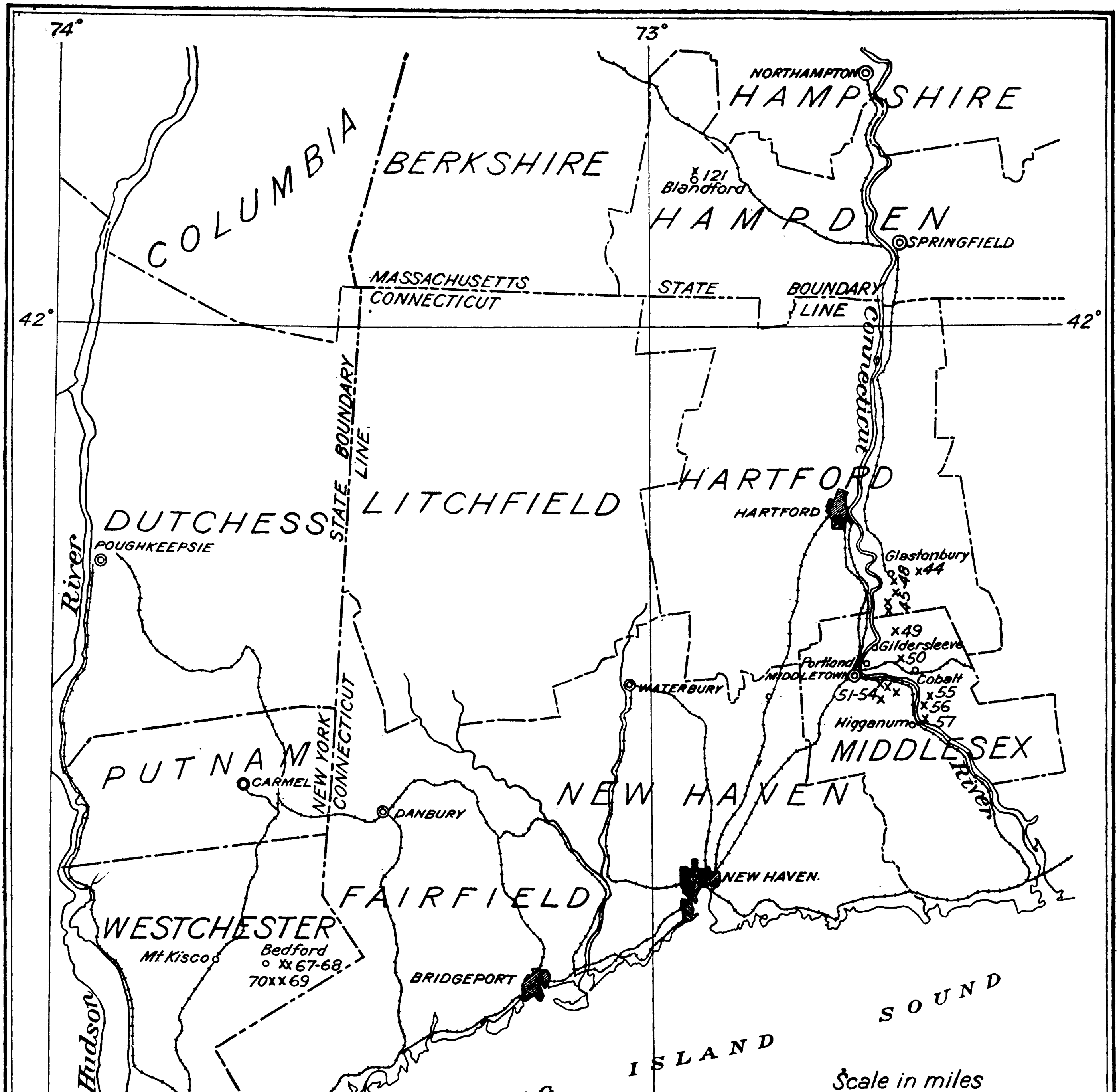
MASSACHUSETTS.

HAMPTON COUNTY.

RUSSELL. BLANDFORD QUARRY.

The Blandford quarry (121) is one-half mile north of Blandford and 4 miles from the railroad at Russell, Mass., in a dike exposed along a ridge running northwest and southeast. The dike is composed of

[a] For a description of this deposit see Bastin, E. S., Economic geology of the feldspar deposits of the United States: Bull. 420, U. S. Geol. Survey, 1910, pp. 26-27.



SKETCH MAP OF PARTS OF CONNECTICUT, NEW YORK (SEE ALSO PL. VI), AND MASSACHUSETTS, SHOWING FELDSPAR DEPOSITS INVESTIGATED. FOR DESCRIPTION OF DEPOSITS SEE TABLE 2.

several bands of pegmatite, varying widely in their feldspar content. Some of the bands are 12 to 15 feet wide in places and have a considerable content of massive feldspar; the deposit also contains much massive white sugar quartz. The property has been opened both on the hilltop and along the face. In one place an opening about 60 feet long and 20 feet wide has been made, and along the walls of the dike considerable muscovite of good quality has been removed. At the south end of this opening the feldspar is about 10 feet wide; whereas at the north end the sugar quartz has almost completely replaced the feldspar. Pure feldspar, however, is observed in smaller openings to the north of this main opening, and it would be assumed that the quartz rapidly pinches out beyond the limits of the main workings. The feldspar appears to be of excellent quality.

The deposit was somewhat covered by refuse from abandoned workings several years old, but samples were obtained by using care. Tests of the samples indicate that the range of deformation lies between 1,270° and 1,285° C. The feldspar is slightly more creamy than the Maine feldspar, but nevertheless is of excellent quality. In the standard porcelain body it has a shrinkage of 15 per cent and a translucency of 0.633.

CONNECTICUT.

HARTFORD COUNTY.

SOUTH GLASTONBURY. CURTIS QUARRY.

The Curtis quarry (44) is located in a deposit[a] 3 miles east of South Glastonbury. Two openings have been made, and in each of them the deposit strikes northeast and has vertical walls. The larger of these openings, which extends the full width of the dike, is about 30 feet wide and 300 feet long; the smaller one is about 150 feet long and 12 feet wide. The maximum depth of the workings is about 25 feet and the quality seems to be continuous, at least to this depth. The dike is composed of fine-grained pegmatite that contains cream-colored feldspar. No masses of pure feldspar larger than a few inches in diameter were noted. Considerable muscovite is scattered through the deposit, but it is practically all of small size and the quality seriously injured by ruling. Garnet occurs at a number of places in the deposit, but is not present over large areas and hence is not a serious detriment.

The extent of the deposit could not be definitely determined owing to the operations being confined to this property, but tests made on

[a] For a description of this deposit see Bastin, E. S., Economic geology of the feldspar deposits of the United States: Bull. 420, U. S. Geol. Survey, 1910, p. 42.

property adjoining on the east indicates that the dike continues with reasonable uniformity in that direction for a considerable distance.

The pegmatite in this deposit was tested and found to have a deformation range of 1,280° to 1,295° C., and to be notably affected by the high quartz content. In the standard porcelain mixture the shrinkage was 13 per cent and the translucency 0.663. This translucency is remarkably high for the shrinkage properties displayed.

SOUTH GLASTONBURY. WIARDA QUARRY.

The Wiarda quarry (45) is located in a feldspar deposit [a] on a north and south ridge on the outskirts of South Glastonbury. Several irregular dikes are exposed, but little actual development work has been done to indicate the continuity of any particular dike or to ascertain the width of the bands rich in feldspar. A good quality of feldspar and graphic granite have been obtained from this property and 2,000 tons were reported as being quarried in 1911. The overburden is very light. The deposit does not differ materially from that of the Howe quarry, of which it is undoubtedly a continuation.

Muscovite and biotite are observed in some of the openings, but little merchantable mica of the white variety is noted. The feldspar is of a creamy color and has a deformation range of 1,275° C. to 1,290° C. It fuses to a semitransparent mass with a faint blue cast.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

The standard porcelain mixture of this feldspar vitrifies at 1,290° C., and at 1,330° C. No warpage is noted. The color is slightly inferior to that of the standard trial. Fired at 1,330° C. the total shrinkage is 14.4 per cent, the translucency is 0.643, and the color by transmitted light is cream white. The color is not affected by either the raw-lead or the fritted glaze.

SOUTH GLASTONBURY. OLD WIARDA QUARRY.

The old Wiarda quarry [b] (46) is 1 mile south of South Glastonbury and one-eighth mile east of the highway. The quarry, which has been abandoned, worked a deposit consisting of several small dikes or stringers, evidently of the same dike that furnishes the pegmatite farther south. This dike is a mixture of fine-grained pegmatite and graphic granite. The feldspar is chiefly microcline of a light-buff color mixed with a small amount of albite. This feldspar when free from quartz has a deformation range of 1,270° C. to 1,285° C. and fuses to a semitransparent glass of good color.

[a] For a description of this deposit see Bastin, E. S., Economic geology of the feldspar deposits of the United States: Bull. 420, U. S. Geol. Survey, 1910, pp. 44–45.

[b] Bastin, E. S., Loc. cit.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

In the standard porcelain mixture this feldspar vitrifies at 1,280° C. and warps slightly at 1,330° C. The color is seen to be a light gray when compared to the standard trial. Fired at 1,330° C. the total shrinkage is 14.2 per cent, the translucency is 0.640, and the color by transmitted light is cream. The gray color is intensified under the raw-lead and also under the fritted glaze.

SOUTH GLASTONBURY. OLD EUREKA QUARRIES.

Located just north of the Howe quarry are the old Eureka quarries (47), two quarries which appear to contain much commercial feldspar, but which have not been operated for several years. The dike structure is a medium coarse pegmatite containing small lenses of pure feldspar. Iron-bearing minerals show in the exposed faces only in small amount. Samples of the feldspar show a deformation range of 1,270° C. to 1,285° C. and fuse to a semitransparent glass of good color.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

In the standard mixture this feldspar vitrifies at 1,280° C. and warps slightly at 1,330° C. The color is only slightly inferior to that of the standard trial. Fired at 1,330° C. the total shrinkage is 14.2 per cent, the translucency is 0.645, and the color is cream by transmitted light. Under the raw-lead and fritted glazes the color is unaltered.

SOUTH GLASTONBURY. LOUIS W. HOWE QUARRY.

The Louis W. Howe quarry (48), which is the largest operation in Connecticut, is 2 miles south of South Glastonbury and 3 miles east of Rocky Hill.

The deposit[a] consists of an enormous dike, which at the time of visiting had been opened for a distance of 650 feet and an average width of about 100 feet to a depth of 70 feet, showing a good quality of pegmatite the entire depth. The structure is a coarse pegmatite, which in some places grades into graphic granite. Mica is not present in large quantity, but small crystals of muscovite occur throughout the greater part of the deposit, and biotite shows over limited areas at a few places in the part exposed. Garnet is in such small quantity and so well crystallized that its removal by hand sorting is practicable. A few places contain tourmaline of the black variety, which also is easily separated in the hand sorting.

The dike is considerably wider than the opening indicates, but the eastern part is much more impure and is not considered of commercial quality, hence it has not been disturbed. The workings had been carried vertically to a depth of about 70 feet and formed a pit, from which it was necessary to hoist the material by a bucket

[a] For a description of this deposit see Bastin, E. S., Economic geology of the feldspar deposits of the United States: Bull. 420, U. S. Geol. Survey, 1910, pp. 45-46.

system, the water which drains into the quarry being removed by pumping. The formation has been worked in benches 10 feet high and 3½ feet wide. Cars of 1½ tons capacity and running on steel tracks conveyed the material from the face of the workings to the point where it was lifted to the surface by buckets. The material, after being hoisted to the surface, was hand sorted according to quality, and the accepted material conveyed by wagon to the mill at South Glastonbury.

The intimate mixture of feldspar and quartz in this dike precludes the production of a feldspar free from quartz, but by selection the quartz content can be maintained at as low a percentage as is now practicable in the Maine quarries.

The feldspar of this deposit has the following composition:

Composition of feldspar from Louis W. Howe quarry.

	Per cent.
H_2O	0.00
SiO_2	65.64
Al_2O_3	19.10
Fe_2O_3	.14
CaO	Trace.
MgO	Trace.
Na_2O	2.32
K_2O	12.58
	99.78

This feldspar has a deformation range of 1,275° C. to 1,290° C. It fuses to a semitranslucent mass with a faint blue tint.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

In the standard mixture this feldspar vitrifies at 1,290° C. and at 1,330° C. shows no signs of warpage. The color is slightly inferior to that of the standard trial. Fired at 1,330° C., the standard mixture shows a total shrinkage of 14 per cent and has a cream-white color by transmitted light and a translucency of 0.647. This feldspar should be equal to the Maine feldspar for all ceramic purposes if equal care were exercised in the selection.

MIDDLESEX COUNTY.

ROCKY HILL. ANDREWS QUARRY.

The Andrews quarry[a] (49) is located in Portland Township, 4½ miles southeast of Rocky Hill. This dike forms a ridge with a general north and south trend and has been opened to a depth of about 50 feet and a length of about 150 feet. The deposit consists of a graphic granite and fine-grained pegmatite mixture which has a very uniform quartz content and a cream-colored feldspar content. Muscovite is reasonably abundant, but rarely in large crystals, and would have

[a] For a description of this deposit see Bastin, E. S., Economic geology of the feldspar deposits of the United States: Bull. 420, U. S. Geol. Survey, 1910, pp. 50–51.

little commercial importance aside from mica for grinding. Small crystals of black tourmaline and garnet are also scattered through the deposit, and would require removal by hand sorting where very abundant.

An analysis of the material in this deposit is given by Bastin,[a] as follows:

Composition of graphic granite from Andrews quarry.

	Per cent.
SiO_2	71.00
Al_2O_3	16.31
MgO	.00
CaO	.22
Na_2O	3.44
K_2O	8.66
H_2O	.12
	99.75

The material from this deposit, free from other than quartz impurity, was sampled and found to have a deformation range of 1,270° to 1,285° C. It fuses to a semitransparent glass with a faint blue tint.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

In the standard mixture this feldspar vitrifies at 1,280° C., and at 1,330° C. no warping is evident. Its color is similar to that of the standard trial, but shows a faint gray tint. Fired at 1,330° C., the total shrinkage is 13.4 per cent, the translucency is 0.673, and the color a cream white. The raw-lead glaze and the fritted glaze darken the porcelain slightly.

PORTLAND. EUREKA QUARRY.

The Eureka quarry[b] (50) is located 2½ miles northeast of Portland on the west slope of Collins Hill. At the time of visiting the opening was about 185 feet long and 65 feet wide. The deposit consists of a capping of impure schist 5 to 15 feet thick underlaid by pegmatite consisting of cream to white feldspar and gray and white quartz, with small lenses of albite at a number of places. Narrow bands or stringers of material similar to that of the main dike occur on both sides of it. Where exposed the dike seems to be about 12 to 20 feet wide and the west dike or stringer seems to be exceptionally high in soda feldspar. This property had been opened to a depth of 30 feet in the main cut and a smaller dike to the west had been opened on a level about 30 feet below the main cut.

The pegmatite contains only a moderate quantity of muscovite which is seldom of a commercial quality. Biotite and garnet are present only in a few parts of the dike and could be eliminated with

[a] Bastin, E. S., Op. cit., p. 14.

[b] For a description of this deposit see Bastin, E. S., Op. cit., pp. 51–52.

little difficulty. Black tourmaline is scattered throughout the dike but is coarsely crystalline and does not present any great difficulty in sorting it from the marketable material. This deposit should not be worked for pure feldspar, but by careful selection the quartz content can be maintained sufficiently low to make a high-grade pottery feldspar. The potash feldspar present is a microcline and is intimately intergrown with albite. A sample of this material was cleaned of its free quartz content and an analysis made, showing the following composition:

Composition of feldspar from Eureka quarry.

	Per cent.
Loss on ignition	0.25
SiO_2	65.24
Al_2O_3	19.74
Fe_2O_3	.12
CaO	.00
MgO	.00
Na_2O	3.04
K_2O	11.84
	100.23

This feldspar has a deformation range of 1,270° C. to 1,285° C. It fuses to a semitransparent glass with a faint blue tint. The soda feldspar associated in lenses with the above microcline shows a deformation range of 1,255° C. to 1,265° C. Its color when fused is an excellent enamel white.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

In the standard mixture the potash feldspar vitrifies at 1,280° C. and does not warp at 1,330° C. The color is slightly below that of the standard trial. Fired at 1,330° C. the total shrinkage is 14 per cent, the translucency is 0.653, and the color cream white. The color of the porcelain is unaltered under the fritted glaze but under the raw-lead glaze is slightly darker.

The soda feldspar in the standard porcelain mixture vitrifies at 1,260° C. and at 1,330° C. shows slight warpage. The color is a matt white. Fired at 1,330° C. the total shrinkage is 13.2 per cent and the translucency is 0.643. The color is not altered under the raw-lead and the fritted glazes.

MIDDLETOWN. RIVERSIDE QUARRIES.

One-fourth mile west of the Consolidated quarry and near the Connecticut River are two dikes (51, 52) of coarse pegmatite containing much massive sugar quartz from which the hill has received the name of White Rock Ridges. The extent of the dikes has never been determined, but there are numerous exposures over a considerable area. The general strike of the dike is nearly due north and south. The dike farthest west is a mixture of graphic granite and coarse buff pegmatite. A small amount of garnet and biotite are the chief impurities. This dike has been worked on a limited scale at a number of points and shows fair uniformity wherever opened.

The east dike is a widely varying mixture of potash feldspar pegmatite and soda feldspar pegmatite. It is much smaller in extent than the west dike and shows a structure similar to the gem bearing dikes of Maine. Much clevelandite is scattered through this dike, and black, pink, and green tourmaline are noted, although the tourmalines are all opaque and not of the gem quality. The albite parts of the deposits are of doubtful value, but the potash feldspar pegmatite, which is similar in both dikes, shows a good color and has a deformation range of 1,275° to 1,290° C.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

This feldspar, in the standard porcelain mixture, gives a vitrious product at 1,290° C. and shows no warpage at 1,330° C. The color is equal to that of the standard trial. At 1,330° C. the translucency is 0.680 and the total shrinkage is 13.9 per cent. The color is unaltered under either the raw-lead or the fritted glaze.

MIDDLETOWN. CONSOLIDATED QUARRY.

The Consolidated Feldspar quarry[a] (53) is located 3 miles east of Middletown, Conn., at an elevation of nearly 500 feet above the Connecticut River. The dike has been opened along a northeast face, showing a width of about 50 feet. The composition of the dike is decidedly variable. In many places it is remarkably free from impurity and shows considerable masses of pure buff feldspar of the potash variety; in others it is very fine-grained pegmatite with much mica and small garnets. The gradation is so pronounced, however, that no difficulty in sorting would be experienced.

The feldspar content of this dike was sampled and shows by chemical analysis the following composition:

Composition of feldspar from Consolidated Feldspar quarry.

	Per cent.
SiO_2	66.03
Al_2O_3	18.99
Fe_2O_3	0.08
CaO	None.
MgO	None.
Na_2O	3.12
K_2O	10.96
	99.18

It has a deformation range from 1,275° to 1,290° C. and fuses to a translucent mass free from tint.

[a] For a description of this deposit see Bastin, E. S., Economic geology of the feldspar deposits of the United States: Bull. 420, U. S. Geol. Survey, 1910, pp. 49-50.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

In the standard porcelain mixture this feldspar vitrifies at 1,280° C. and at 1,330° C. shows no evidence of warping. The color is equal to that of the standard trial and does not alter under either the raw lead or the fritted glaze. Fired at 1,330° C., the total shrinkage is 14.2 per cent and the translucency is 0.673 and the color cream white.

MIDDLETOWN. BIDWELL QUARRY.

The Bidwell quarry (54) is located 2½ miles south of Middletown, on Haddam Pike. The quarry was worked about 40 years ago, and recently has been reopened and worked for its pegmatite. The deposit consists of a dike which strikes due north and has been mined to a depth of 20 feet for a distance of about 200 feet. The material removed is reported to have been buff potash feldspar, but that now exposed in the walls and floor consists of about equal proportions of microcline and albite. This quarry should produce a considerable amount of mixed feldspar high in soda content and valuable for softening the feldspars high in potash. An average sample of the feldspar shows a deformation range of 1,265° to 1,275° C. and fuses to a semiopaque enamel of good white color.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

In the standard porcelain mixture this feldspar vitrifies at 1,270° C. and shows pronounced warping at 1,330° C. The color is a faint gray. Fired at 1,330° C. the shrinkage is 13.8 per cent and the translucency is 0.630 and the color is cream. The application of raw lead and fritted glazes intensifies slightly the gray tint of the unglazed porcelain.

MIDDLE HADDAM. HALLBERG DEPOSIT.

The Hallberg deposit (55), 2 miles southeast of Middle Haddam village, does not differ materially from the one at the Middle Haddam quarry, except that gem minerals are absent. The dike is opened by a pit at its northeast terminus on an abrupt bluff of a hill. The width of the dike where exposed in this pit is about 20 feet, and a face about 20 feet high has been uncovered.

The pegmatite in this deposit was sampled and found to have a deformation temperature of from 1,270° to 1,285° C.

It fuses to a semitransparent glass with a faint blue tint.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

In the standard mixture the above feldspar vitrifies at 1,280° C. and at 1,330° C. a slight warpage is noted. Fired at 1,330° C., the total shrinkage is 14.5 per cent, the translucency is 0.657, and the color is cream. The porcelain shows a faint gray tint which is intensified by the application of both the raw lead and the fritted glaze.

MIDDLE HADDAM. MIDDLE HADDAM QUARRY.

The Middle Haddam quarry (56), 1½ miles southeast of Middle Haddam village, consists of a number of small openings scattered over a territory comprising several hundred acres. The largest single operation consists of an opening in the west slope of a hill overlooking the Connecticut River and the dike where exposed seems to be about 40 feet wide and to have a general northeasterly strike. This deposit is about one-half of a mile from the river and the material is hauled to the face of an abrupt cliff and dumped into lighters moored below it. The product of the quarry is a granite pegmatite, practically no lenses of pure feldspar being observed. Crystals of muscovite of moderate size occur at frequent intervals, but few specimens of commercial value are noted. Black tourmaline and biotite are scattered through the deposit and require careful hand sorting to eliminate them. The occurrence of lepidolite and colored tourmaline are reported from this deposit, but none was observed at the time of its inspection. The cleaner parts of the pegmatite were sampled and found to have a deformation temperature of 1,270° to 1,285° C. When fused the feldspar is semitransparent and has a faint blue tint.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

In the standard porcelain mixture this feldspar vitrifies at 1,280° C., and at 1,330° C. warps slightly and has a faint gray tint. When fired at 1,330° C. the total shrinkage is 14 per cent and the translucency is 0.630 and the color is cream. Under the raw-lead and fritted glazes the gray tint is somewhat intensified.

HADDAM. HADDAM NECK QUARRY.

Haddam Neck quarry (57) is located on the east bank of the Connecticut River, opposite Haddam village. This deposit consists of a dike about 100 feet wide and has been worked for a distance of about 350 feet and to a depth of about 30 feet. The deposit contains a variable pegmatite with many inclosed masses of albite and small lenses of microcline; graphic granite was exposed in many parts of the quarry when visited. The pegmatite is mixed with micas, black tourmaline, garnet, and other minerals and many gems are reported as being found in this quarry. The feldspar is a buff microcline intergrown with albite of a white and pale-green color. Free from quartz, this feldspar shows a deformation range from 1,266° to 1,285° C., and when fused is semitransparent and has a good color.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

In the standard porcelain mixture this feldspar vitrifies at 1,280° C., and at 1,330° C. no warping is noted. The color is almost equal to that of the standard trial. Fired at 1,330° C. the total shrinkage is 14 per cent and the translucency is 0.637 and the color is cream white. The color is not altered under the raw-lead and fritted glazes.

NEW HAVEN COUNTY.

OXFORD. BRIDGEPORT QUARRY.

The Bridgeport quarry is located about 1½ miles south of Oxford, Conn. This quarry is an open pit about 150 by 100 feet in size and the deposit[a] seems to be an isolated lens of pegmatite which apparently does not continue in either direction. The quarry has been abandoned some time and at the time of visiting was filled with water so that no estimate of what its content was, or what material the walls are, could be formed. The parts exposed above the water consist largely of a coarse pegmatite with isolated lenses of feldspar of widely varying color and structure. The quartz in this quarry is reported as having been rose quartz and massive white sugar quartz. The quantity of feldspar exposed is not sufficient to justify a statement regarding the probable quality of the feldspathic material of the deposit.

NEW YORK.

All the feldspar deposits investigated in New York are shown in Plate VI except those in Westchester County, which are shown in Plate V.

ESSEX COUNTY.

CROWN POINT. CROWN POINT QUARRY.

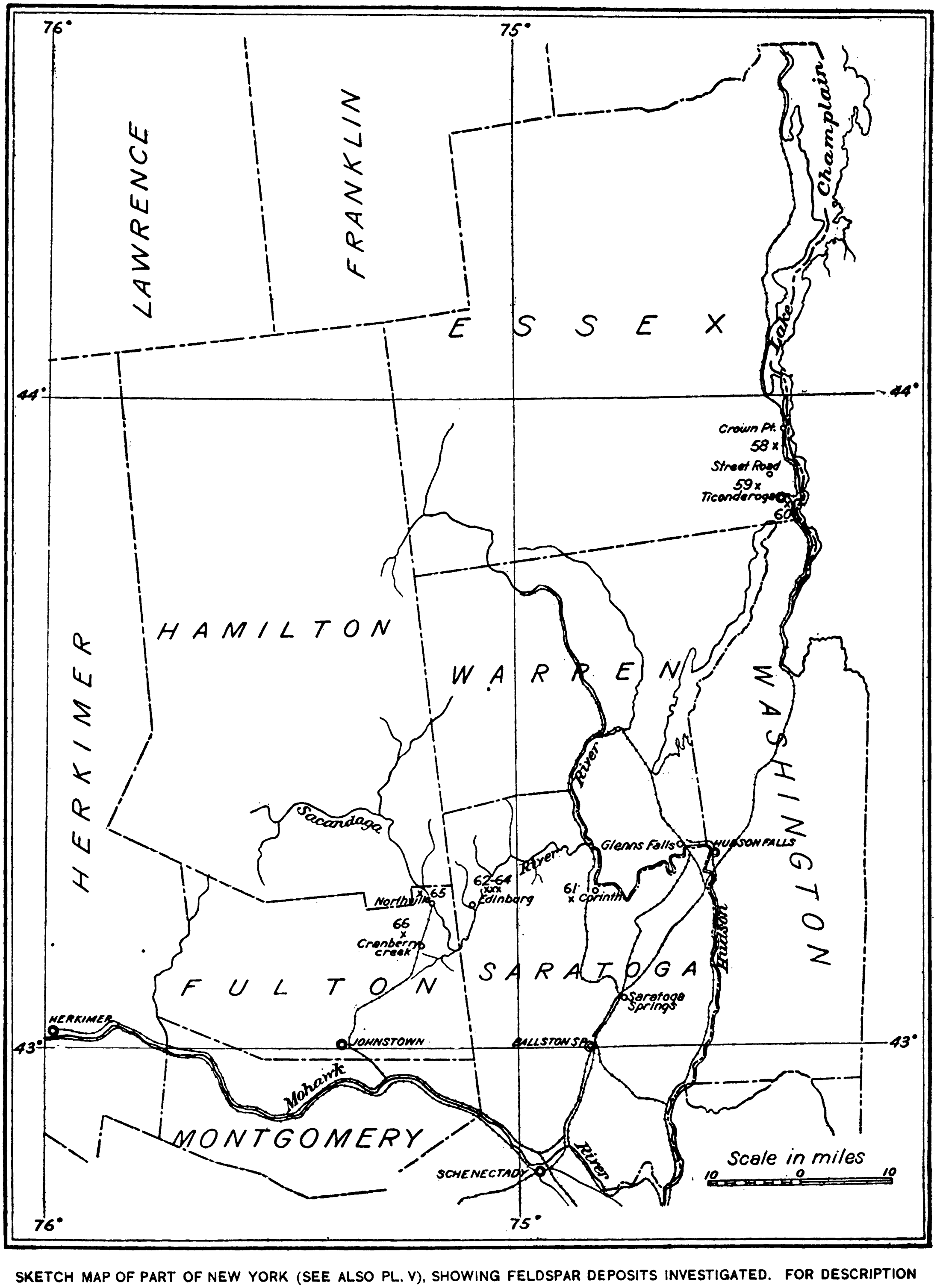
The Crown Point quarry (58) is 2 miles southwest of Crown Point and 1 mile west of Lake Champlain. The deposit[b] is an expanded pegmatite dike, of widely varying composition, with a northeast strike. The dip is uncertain, but is almost vertical where exposed by quarrying for a width of about 40 feet.

The pegmatite is a coarse mixture of pearl-gray microcline and green plagioclase with variable contents of quartz and leaves of biotite along the contact faces between the masses of microcline and plagioclase. In this quarry the central part of the dike contains more microcline than plagioclase, and along the walls the plagioclase appears to predominate. Along the west wall a hematite-red stain occurs on the faces of the microcline crystals, but does not penetrate the feldspar masses. The overburden varies from nothing to 4 feet and is a soil made up largely of weathered dike material.

The nature of the deposit would demand great care in selecting the feldspar if it were to be marketed for ceramic uses. Many parts are so mixed with biotite that cleaning would be impracticable, but at least one-third of this dike would justify cobbing for its microcline. The mining at present is for material to be used in the manufacture of roofing and for poultry grit, and for these purposes the run of the quarry can be used without cleaning of any impurity except the small

[a] For a description of this deposit see Bastin, E. S., Economic geology of the feldspar deposits of the United States: Bull. 420, U. S. Geol. Survey, 1910, pp. 53-54.

[b] See Bastin, E. S., Op. cit., pp. 54-55.



SKETCH MAP OF PART OF NEW YORK (SEE ALSO PL. V), SHOWING FELDSPAR DEPOSITS INVESTIGATED. FOR DESCRIPTION OF DEPOSITS SEE TABLE 2.

flake mica. The greater part of the mica can be eliminated by means of a screen, as it does not pulverize with the feldspar.

Although the output of pottery feldspar from such a deposit would necessarily vary greatly in different parts of the dike, the small quartz content would make such good feldspar as was obtained of especial value for the improvement of pegmatite high in quartz and would eliminate the necessity of robbing other dikes of their select feldspar for this purpose.

The two types of feldspar present in the dike were sampled separately and tested.

The microcline is found to have the following chemical composition:

Composition of microcline from Crown Point quarry.

	Per cent.
Ignition loss	0.40
SiO_2	63.61
Al_2O_3	19.09
Fe_2O_3	.43
TiO_2	.02
CaO	.54
MgO	.17
BaO	.15
K_2O	14.07
Na_2O	1.73
	100.21

The microcline has a deformation range of 1,270° to 1,285° C. and fuses to a semitransparent glass of faultless color. The plagioclase has a deformation range of 1,280° to 1,290° C. and fuses to a light brown slag. From 400° C. until deformation begins this plagioclase is a hematite-red color, and at 1,275° C. shows no signs of vitrification.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

The microcline of this deposit, when prepared in the standard porcelain mixture, vitrifies at 1,280° C., and at 1,330° C. shows no warpage. Fired at 1,330° C. the total shrinkage is 14.6 per cent, the translucency is 0.84, and the color is cream white. The color is equal to that of the standard trial and is not altered under either the raw-lead or the fritted glaze.

TICONDEROGA. BARRETT QUARRY.

The Barrett quarry (59) is 1¾ miles northwest of Ticonderoga, and almost due south of Crown Point quarry. The deposit,[a] which closely resembles that at the Crown quarry, as regards structure and constituents, is a dike 100 to 150 feet wide, and is exposed for about 1,200 feet along the east slope of a ridge which strikes northeast and dips 35° SE. The dike is opened to a maximum depth of 60 feet. The pegmatite exposed is a coarse mixture of pearl-gray microcline and pale-green plagioclase, the analysis of which shows it to be

[a] For a description of this deposit see Bastin, E. S., Economic geology of the feldspar deposits of the United States: Bull. 420, U. S. Geol. Survey, 1910, pp. 55-56.

andesine. Biotite is very abundant and is distributed throughout the dike. It generally occurs along the contacts between the microcline and the oligoclase, and as neither feldspar averages masses more than 5 or 6 inches in diameter, the removal of the biotite presents a serious problem. Where the oligoclase is not so abundant the microcline occurs with the quartz as graphic granite. The biotite in this dike is remarkably tough and does not reduce to a powder when passed through the crushing machinery employed to reduce the feldspar to the proper size for roof covering, for which purpose the output of the quarry is used. The microcline has a very highly developed cleavage and attempts at cobbing result in its breaking into fragments of one-fourth to one-sixteenth inch in diameter. The logical method of cleaning this microcline is to granulate it and then separate it from the biotite by screening or blowing. Up to March, 1915, all attempts to eliminate the biotite completely have failed, and it is doubtful if this deposit can be made to produce a large amount of high-grade feldspar unless some special system of separating the biotite can be developed.

The feldspar constituents of the dike were sampled carefully and found by analysis to have the following compositions:

Composition of feldspar constituents of Barrett deposit.

	Pearl-gray microcline.	Pale green andesine.
Ignition loss........per cent..	0. 18	0. 58
SiO_2........do....	64. 55	59. 35
Al_2O_3........do....	18. 90	25. 30
Fe_2O_3........do....	. 36	. 57
TiO_2........do....	. 03	. 03
CaO........do....	. 51	6. 43
MgO........do....	. 19	. 00
BaO........do....	. 19	. 00
K_2O........do....	12. 32	1. 35
Na_2O........do....	2. 88	6. 26
	100. 11	99. 87

The microcline has a deformation range of 1,260° to 1,275° C. and fuses to a semitransparent glass of faultless color.

The andesine has a deformation range of 1,330° to 1,335° C. and fuses to a light-brown slag. From 400° C. until deformation begins the andesine is a hematite red and shows no signs of vitrification at 1,275° C., although it contains more than 60 per cent albite.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

In the standard porcelain mixture the microcline vitrifies at 1,270° C. and at 1,330° C. warps slightly. Fired at 1,330° C. the total shrinkage is 13.7 per cent and the translucency is 0.86 and the color is cream white. The color of the porcelain is equal to that of the standard trial and is not altered under either the raw-lead or the fritted glaze.

TICONDEROGA. TICONDEROGA QUARRY.

The Ticonderoga quarry (60) is 1 mile southeast of Ticonderoga, an the south side of the railroad between Ticonderoga and Mont Calm Landing, in a small glen facing northeast and having very abrupt walls. A face about 60 feet high and 30 feet wide has been worked for a depth of about 20 feet. The dike consists of a medium coarse pegmatite with massive intrusions of calcite and these calcite masses, as well as the lines of contact between the feldspar and the calcite, carry large amounts of finely crystallized hornblende. The dike is so completely charged with these minerals that the production of a pure feldspar would be very expensive if not quite impossible.

SARATOGA COUNTY.

CORINTH. CORINTH QUARRY.

The Corinth feldspar quarry [a] (61) is 2½ miles southwest of Corinth station. The quarry consists of a small pit opened on the east face of a hill, and another and larger opening 100 yards distant and 125 feet higher, and following the strike of the dike for about 50 feet. This latter opening is so shallow, however, that it is doubtful if it shows the true nature of the dike, as the lines of contact and capping often show more impurity than the body of the dike, and the associated minerals exposed, garnet and biotite, are similar to those of the inclosing rocks, which are schists. The lower opening is a very pure pegmatite and graphic granite consisting of pearl-gray microcline and smoky quartz. No other minerals are present.

The chief difficulty in the development of this property is the poor road to the railroad, but if the road was improved the expense of hauling, as almost the entire distance is down hill, could be reduced to the minimum. The two pits were sampled separately and tested.

The feldspar of the upper pit shows a deformation range of 1,255° to 1,265° C., and when fused is almost transparent and free from tint.

The feldspar of the lower pit shows a deformation range of 1,260° to 1,270° C., and when fused is semitransparent and free from tint.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

In the standard porcelain mixture the feldspar of the upper pit vitrifies at 1,260° C. and at 1,330° C. warping is evident. Fired at 1,330° C. the total shrinkage is 14.8 per cent, the translucency is 0.74, and the color is cream white. The color of the porcelain is equal to that of the standard trial and is not altered under either the raw-lead or fritted glaze.

In the standard porcelain mixture the feldspar of the lower pit vitrifies at 1,270° C., and at 1,330° C. no warpage is apparent. Fired at 1,330° C. the total shrinkage

[a] For a description of this deposit see Bastin, E. S., Economic geology of the feldspar deposits of the United States: Bull. 420, U. S. Geol. Survey, 1910, pp. 57-58.

is 15 per cent, the translucency is 0.83, and the color is cream white. The color is equal to that of the standard trial and is not altered under either the raw-lead or the fritted glaze.

BATCHELLERVILLE. BATCHELLERVILLE QUARRIES.

The Batchellerville quarries (62) are 2 miles north of Batchellerville and one-fourth mile east of the Day-Batchellerville road.

Main Quarry.

The main quarry is on a west slope and is in full view of the road.[a] At the time of visiting it consisted of a cut about 60 feet long and 35 feet wide into a pegmatite dike which strikes northeast and stands almost vertical. The cut slopes into the hill and was filled with water to the entrance, but a face 20 feet high was exposed above the water. The pegmatite, which is coarsely crystalline, consists of cream and pearl-gray microcline and white albite mixed with gray quartz. Rose-colored sugar quartz is present in large masses. A small lens of pure albite was noted in the floor near the entrance. Muscovite is present, but is segregated and could be easily eliminated in handling the quarried material. Beryl is found, but is of a dark blue color and would be quickly recognized and rejected in handling the material. The limited quantity of biotite would present no serious difficulty in mining the feldspar.

The wall rock is a biotite gneiss, and there is a horse of similar rock in the center of the dike, but it is perfectly solid and would not present any serious hindrance to quarrying.

Samples of the microcline were obtained free from albite and quartz, and this shows a deformation range of 1,270° to 1,285° C. It fuses to a glass which is semitransparent and free from tint.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

In the standard porcelain mixture this feldspar vitrifies at 1,280° C., and at 1,330° C. shows no sign of warping. Fired at 1,330° C. the total shrinkage is 15 per cent, the translucency is 0.78, and the color is cream white. The color is equal to that of the standard trial and is not affected by the raw-lead and fritted glazes.

Second Quarry.

A second quarry is located about 100 yards east of the main quarry and on the strike of the same dike, but on ground 60 feet higher. This opening was only about 20 feet wide and 30 feet long, and had a maximum depth of 10 feet. The composition of the dike at this point is slightly different, although in most respects it is similar to the lower quarry exposure. The microcline is entirely of the pearl-gray

[a] For a description of this deposit see Bastin, E. S., Economic geology of the feldspar deposits of the United States: Bull. 420, U. S. Geol. Survey, 1910, pp. 58-59.

variety. Muscovite is present in only limited amount and no biotite is noted. Dark-red, cloudy garnets are noted in limited numbers, but these are generally large and hence easily detected and removed. Some graphic granite occurs in the walls of this opening, but its quartz content is very low.

A careful average was made of the feldspar content of this part of the dike, and this shows by analysis the following composition:

Composition of selected feldspar from smaller quarry.

	Per cent.
Ignition loss	0.26
SiO_2	65.14
Al_2O_3	19.38
Fe_2O_3	.29
TiO_2	.01
CaO	.44
MgO	.14
BaO	.00
K_2O	11.28
Na_2O	3.61
	100.55

This feldspar has a deformation range of 1,250° to 1,260° C. and fuses to an almost transparent glass of excellent color. The small content of CaO and MgO exert a remarkable influence in lowering the deformation temperature and shortening the deformation range. The presence of 0.29 per cent of Fe_2O_3 would be expected to produce a tint, but none is apparent.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

In the standard porcelain mixture this feldspar vitrifies at 1,260° C., and at 1,330° C. the warpage is very pronounced. Fired at 1,330° C. the total shrinkage is 13.6 per cent, the translucency is 0.86, and the color is cream white. The color of the porcelain is equal to that of the standard trial, and the color is not altered under either the raw-lead or the fritted glaze.

THIRD QUARRY.

A third quarry (63) which has been worked only in a very primitive way is located one-fourth mile east of the upper quarry in a glen. Its location would indicate that this deposit is a continuation of the one worked in the two openings nearer the highway, especially as pegmatite is encountered by removing the surface soil in many places between the quarries. The appearance of the dike is, however, very different. Masses of deep salmon and pink feldspar of the microcline variety are exposed in a creek bed, and associated with this is a pegmatite consisting of pale pink feldspar and clear white quartz. The dark salmon and pink feldspar free from quartz have been removed from an opening 30 feet long and 20 feet wide and having an estimated depth of 12 feet. This pink and salmon feldspar were sampled and tested separately. The salmon feldspar, which predominates, was analyzed and found to have the following composition:

Composition of salmon feldspar from third quarry.

	Per cent.
Ignition loss	0.17
SiO_2	64.26
Al_2O_3	18.78
Fe_2O_3	.43
TiO_2	.00
CaO	.33
MgO	.14
BaO	.00
K_2O	14.15
Na_2O	2.01
	100.27

This feldspar shows a deformation range of 1,275° to 1,290° C. and fuses to a semitransparent mass with a fair color, but not equal to that of the lighter-colored feldspars. The pink feldspar has the same range and temperature of deformation as the salmon feldspar.

A sample of the pale pink feldspar was obtained from an exposure midway between the second and third quarries. This feldspar was found to have a deformation range of 1,265° to 1,275° C. and when fused it becomes almost transparent and free from tint.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

Salmon feldspar.—In the standard porcelain mixture the salmon feldspar vitrifies at 1,280° C., and at 1,330° C. shows no evidence of warping. When fired at 1,330° C. the total shrinkage is 13.6 per cent, the translucency is 0.82, and the color is cream white. The color of the porcelain is equal to that of the standard trial, and is not altered under either the raw-lead or the fritted glaze.

Pale pink feldspar.—In the standard porcelain mixture the pale pink feldspar vitrifies at 1,270° C., and at 1,330° C. showed slight warping. Fired at 1,330 C., the color is equal to that of the standard trial, the total shrinkage is 15.2 per cent, the translucency is 0.86, and the color by transmitted light is cream white. The color of the porcelain is not affected by application of either raw-lead or fritted glaze.

HAMILTON COUNTY.

NORTHVILLE. SNELL PROSPECTS.

On the Herbert Snell property (63) in Benson Township, Hamilton County, 4 miles north of Northville, Fulton County, numerous exposures of pegmatite were noted, the most promising being on a hill west of the highway, where a dike about 15 feet wide is exposed at two places. The deposit has a general northeast strike, and stands nearly vertical. Very little biotite or tourmaline were exposed and the pegmatite seems remarkably pure except for occasional lenses of massive quartz. The feldspar is principally a pale salmon microcline, but a short distance off the strike a small exposure of pearl-gray microline was noted.

The salmon feldspar was sampled and tested. It has a deformation range of 1,255° to 1,265° C., and when fused it is practically transparent and free from tint.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

In the standard mixture the feldspar vitrifies at 1,260° C. and at 1,330° C. shows warping distinctly. Its color is equal to that of the standard trial. ·Fired at 1,330° C. the total shrinkage is only 13 per cent; the color is cream white, and the translucency is 0.82. The color is not altered under the raw-lead and fritted glazes.

FULTON COUNTY.

NORTHVILLE. RHODES QUARRY.

The Rhodes quarry (64) is located about 3 miles northeast of Northville, Fulton County, near the Saratoga County line. This quarry was opened about 20 years ago and only a small quantity of feldspar has been removed. The opening, which is 20 by 30 feet, is filled with water and no data on the deposit could be obtained except from a quantity of clean feldspar, estimated at 30 tons, which is heaped about the opening. About 6 tons of massive quartz is also heaped near the quarry. There is a notable absence of pegmatite in this deposit and the only mineral noted aside from feldspar and massive quartz is clear mica, for which the quarry was originally opened. The feldspar is a buff microline intergrown with thin layers of quartz. These quartz layers constitute approximately 25 per cent of the mass. A sample representing the average of the heaps of feldspar showed a deformation range of 1,330° to 1,350° C. and fused to a semitransparent glass with remarkable freedom from color.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

In the standard mixture this feldspar produces a vitrious mass at 1,350° C. The color is equal to that of the standard trial. Fired at 1,330° C. the feldspar has a cream-white color and a translucency of 0.77, and a total shrinkage of 14.2 per cent. The color is not altered by the raw-lead and fritted glazes.

NORTHVILLE. GIFFORD PROSPECT.

The Gifford prospect (65) is 1½ miles west of Northville, in a pegmatite dike, 6 to 10 feet wide, which can be traced for one-half mile along an east slope. The degree of purity varies in the exposed faces, but as no development work had been done only surface indications could be noted. In many places lenses of pure feldspar 1 to 2 feet square are exposed, the degree of purity seeming to increase toward the south end of the dike. The feldspar is principally buff microcline, but pale salmon microcline is noted at a few points.

The buff microcline was sampled and tested. It has a deformation range of 1,265° to 1,275° C. and when fused is semitransparent and free from tint.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

In the standard mixture the feldspar vitrifies at 1,270° and at 1,330° C. warping is apparent. The color is equal to that of the standard trial. Fired at 1,330° C. the porcelain has a cream-white color by transmitted light, a translucency of 0.76, and a total shrinkage of 15 per cent. The color is not altered under the raw-lead and fritted glazes.

CRANBERRY. TYROL MOUNTAIN QUARRY.

The Tyrol Mountain quarry (66) is 2½ miles west of Cranberry station, in the crest of the Tyrol Mountain.

The dike [a] is exposed on a south slope and consists of a number of distinct bands. Some of these are very impure whereas others are almost free from minerals other than feldspar and quartz. At the time of visiting a mass of very impure pegmatite, which had been opened by the last operator of this property and not removed, the quarry face being covered with débris. Lenses of clean pegmatite were exposed on both sides of this impure mass and much high-grade pottery material may still be expected from this property. A lens of plagioclase, which is shown by analysis to be andesine, and much clean microcline pegmatite was exposed in the floor of the quarry.

The location of this deposit, about 1,000 feet above the railroad, indicated a very steep road and, although down hill, the conveying of the material to the railroad presents difficulties which could be overcome only by building a road of more gradual slope.

The results of an analysis of the andesine is as follows:

Composition of andesine from Tyrol Mountain quarry.

	Per cent.
Ignition loss	0.54
SiO_2	61.91
Al_2O_3	23.69
Fe_2O_3	.40
TiO_2	
CaO	4.37
MgO	.13
K_2O	1.17
Na_2O	8.40
	100.61

It shows a deformation range of 1290° to 1300° C. and fuses to a clear white enamel.

The pegmatite, which constitutes the vast majority of the deposit, is buff microcline and quartz. It deforms at 1270° to 1280° C. and fuses to almost a transparent glass without tint.

[a] For a description of this deposit see Bastin, E. S., Economic geology of the feldspar deposits of the United States: Bull. 420, U. S. Geol. Survey, 1910, pp. 56–57.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

Andesine.—In the standard mixture this andesine vitrifies at 1,300° C. and has a cream white color by transmitted light, a translucency of 0.76, and a total shrinkage of 14 per cent.

Microcline.—In this mixture the above microcline vitrifies at 1,280° C. and at 1,330° C. shows no warpage. Fired at 1,330° the microcline has a total shrinkage of 13.6 per cent, a cream white color by transmitted light and a translucency of 0.78. The color is equal to that of the standard trial and is not altered by the raw-lead and fritted glazes.

WESTCHESTER COUNTY.

BEDFORD. BEDFORD QUARRY.

The Bedford quarry (67) is located on the north slope of a hill, 1 mile east of Bedford village. The deposit is a dike or a stringer from the main dike which forms the central part of the hill and is worked at the Kinkel quarry. At the Bedford quarry it consists of two principal forms of feldspar, a buff microcline pegmatite and a white albite pegmatite. Associated with the microcline is a dark buff feldspar of the potash variety and almost free from quartz. The chief associate minerals are the micas, the biotite being in small crystals and associated chiefly with the albite pegmatite whereas the muscovite is distributed through the microcline pegmatite, but not in injurious quantity. The muscovite is extremely tough and withstands abrasion, and the major part of it could be eliminated by screening the material after a short preliminary grinding.

The entire dike is quarried and sorted. The parts high in albite and the standard feldspar are marketed for less critical uses and the better parts are sold for pottery manufacture. A sample of the pottery feldspar from this quarry has the following composition:

Composition of pottery feldspar from Bedford quarry.

	Per cent.
Ignition loss	0.28
SiO_2	69.45
Al_2O_3	16.76
Fe_2O_3	.20
TiO_2	....
CaO	.45
MgO	.05
BaO	.10
Na_2O	2.60
K_2O	9.80
	99.69

This feldspar has a deformation range of 1,270° to 1,290° C. and fuses to a semitransparent glass free from tint.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

In the standard porcelain mixture this feldspar produces a vitrious mass at 1,290° and shows no evidence of warping at 1,330° C. Fired at 1,330° C. it has a total shrinkage of 15.0 per cent, a cream color by transmitted light, and a translucency of 0.87. The color of the porcelain is slightly cream, but is equal to those of most commercial wares, and is not affected by application of either the raw-lead or the fritted glaze.

BEDFORD. KINKEL QUARRY.

The Kinkel quarry (68) is 1 mile east of Bedford village. The dike [a] into which this quarry has been opened constitutes the central part of a ridge which ends abruptly at this point. This dike has a total width of about 200 feet, but intrusions of material similar to the walls divide it into three sections which have been worked as separate quarries. The structure of this entire dike is extremely coarse. Enormous masses of clear quartz are associated with the feldspar, which is of four general types, namely, salmon microcline, buff graphic granite of the microcline variety, white albite pegmatite of varying coarseness, and a friable white albite evidently well advanced in weathering process.

MICROCLINE PEGMATITE.

The salmon microcline occurs in isolated lenses generally surrounded by massive quartz. It is remarkably free from associate minerals and could be obtained in a high state of purity by hand sorting. An average sample of this microcline has the following chemical composition.

Composition of microcline from Kinkel quarry.

	Per cent.
Ignition loss	0.22
SiO_2	64.82
Al_2O_3	18.87
Fe_2O_3	.29
TiO_2	.01
CaO	.23
MgO	.16
BaO	Trace.
K_2O	13.11
Na_2O	2.70
	100.41

It has a deformation range of 1,270° to 1,290° C. and fuses to a semitransparent glass free from tint.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

In the standard porcelain mixture this feldspar vitrifies at 1,290° and no warping is apparent at 1,330° C. Fired at 1,330° it has a cream-white color by transmitted light, a translucency of 0.78, and a total shrinkage of 14 per cent. The color is equal to that of the standard trial and is not affected by the raw-lead and fritted glazes.

[a] For a description of this deposit see Bastin, E. S., Economic geology of the feldspar deposits of the United States: Bull. 420, 1910, pp. 60-63.

Graphic Granite.

The buff graphic granite, the quantity of which is small compared to that of the salmon microcline, is similar in all respects to that found on the adjoining property of the Bedford Feldspar Co.

Albite Pegmatite.

The albite pegmatite is very important as it constitutes at least 50 per cent of the entire feldspar content of the dike.

The fact that biotite is distributed throughout many parts of this albite pegmatite will necessitate careful sorting if the more impure parts are to be rendered suitable for pottery uses. Much of the pegmatite, however, contains no biotite or other impurity except quartz and could be easily and cheaply prepared for grinding. Black tourmaline was also noted in some masses of this pegmatite, but not in quantity to constitute a menace. Beryl is also present in small amount.

The quartz content in the albite pegmatite is greater than is generally found in the better grades of microcline pegmatite and causes the pegmatite to resemble graphic granite. An average sample of this albite pegmatite was analyzed and found to have the following composition:

Composition of albite pegmatite from Kinkel quarry.

	Per cent.
Ignition loss	0.40
SiO_2	73.88
Al_2O_3	15.73
Fe_2O_3	.36
TiO_2	.01
CaO	.86
MgO	.36
BaO	
K_2O	.48
Na_2O	7.97
	100.05

It has a deformation range of 1,260° to 1,270° C. and it fuses to a pure white enamel.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

In the standard mixture the albite pegmatite produced a vitreous mass with the peculiar nonmetallic ring when struck, which is characteristic of soda feldspar porcelains.

Fired at 1,330° C. it had a cream-white color by transmitted light, a translucency of 0.78, and a total shrinkage of 11.8 per cent. The porcelain had an excellent color but possessed a slight vesicular structure and was slightly warped, both being evidence of its having been overfired. It also lacked the brilliant fracture of porcelains containing potash feldspars. Under the raw-lead and fritted glazes the color of the porcelain was not altered.

Pure White Albite.

The pure white albite, which occurs in lenses in many parts of this dike, does not constitute a great proportion of the whole, but it must be handled in quarrying, and hence its utilization if practical is important. It is friable and easily crushed in the hand and is generally quite free of associated minerals. In order to remove it without danger of contamination, especial care must be exercised owing to its brittleness. Tests conducted upon average samples of this material indicate that it has a deformation temperature of 1,250° to 1,260° C. and that it fuses to a semitransparent glass.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

In the standard mixture the pure albite produces vitrification at 1,270° and at 1,330° both warping and vesicular structure are evident. The porcelain is a typical soda feldspar porcelain. At 1,330° C. the total shrinkage is 13.4 per cent and the mass has a cream-white color by transmitted light and a translucency of 0.78. The color of the porcelain is not altered under the raw-lead and fritted glazes.

NORTH CASTLE. HOBBY QUARRY.

The Hobby quarry (69) is located in the town of North Castle on the west bank of Mianus River, and about 1½ miles south of the Kinkel quarry. The quarry is on a steep east slope and is about 150 feet long. The dike is an exceedingly coarse mixture of buff microcline and massive quartz, the quartz constituting more than 50 per cent of the whole. The feldspar is exceptionally free from associate minerals other than quartz, except fine intergrowths of albite. This quarry has not been exhausted but is abandoned.

Samples of the buff feldspar which constitutes the entire feldspar content of this quarry show a deformation range of 1,265° to 1,275° C. and fuse to a semitransparent glass free from tint.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

In the standard porcelain mixture this feldspar vitrifies at 1,270° C. and at 1,330° C. shows very slight warping. Fired at 1,330° C., it has a cream-white color by transmitted light, a translucency of 0.81, and a total shrinkage of 14 per cent. The color of the porcelain is equal to that the standard trial and is not affected by the raw-lead and fritted glazes.

NORTH CASTLE. BULLOCK QUARRY.

The Bullock quarry (70) is 1½ miles south of the Kinkel quarry and one-half mile west of the Hobby quarry. The dike where exposed is about 35 feet wide and has been worked for a distance of about 60 feet and to a depth of about 30 feet. It strikes northeast and dips northwest.

At the time this property was inspected, in May, 1913, the exposure indicated a narrowing of the dike and the operator predicted a much reduced production. About 1,000 tons of feldspar free from quartz has been shipped from this quarry.

The dike consists almost entirely of massive buff microcline, the only associate minerals being insignificant quantities of biotite and black tourmaline and a few scattered "books" of muscovite. Quartz is present only in isolated lenses of sugar quartz. Graphic granite and pegmatite are practically absent.

This feldspar on examination is found to contain a small amount of albite crystallized with the microcline. It has a deformation range of 1,270° to 1,280° C. and fuses to a semitransparent glass free from tint.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

The standard porcelain mixture made with this feldspar vitrifies at 1,280°, and at 1,330° C. no warping is apparent. Fired at 1,330° C., it has a cream-white color by transmitted light, a translucency of 0.76, and a total shrinkage of 14 per cent. The color is equal to that of the standard trial and does not change under the raw-lead and the fritted glazes.

PENNSYLVANIA.

DELAWARE COUNTY.

DARLINGTON. DARLINGTON QUARRY.

The Darlington quarry (71) is 1 mile northeast of Darlington.

This quarry was opened for feldspar and a shallow pit has been dug into the dike. It was later worked for mica by means of shafts. The workings have been abandoned and the shafts filled with water, hence no opportunity to study the dike is provided. About the entrances to the shafts are heaps of albite pegmatite and a small quantity of buff microcline. The albite pegmatite carries an excessive amount of quartz but the microcline is entirely free from quartz.

The albite pegmatite has a deformation range of 1,300° to 1,305° C., and at 1,310° fuses to a shapeless mass of enamel-like material.

The microcline was sampled and analyzed, showing the following composition:

Composition of microcline from Darlington quarry.

	Per cent.
Ignition loss	0.12
SiO_2	64.70
Al_2O_3	19.60
Fe_2O_3	.03
TiO_2	......
CaO	.05
MgO	......
Na_2O	3.76
K_2O	11.87
	100.13

It has a deformation range of 1,280° to 1,290° C. and fuses to a semitransparent glass free from tint.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

In the standard porcelain mixture this feldspar produces a vitreous mass at 1,290° C. and at 1,330° shows no warpage. Fired at 1,330° C., it has a cream-white color by transmitted light, a translucency of 0.87, and a total shrinkage of 13.4 per cent.

The color is equal to that of the standard trial and is not altered under the raw-lead and fritted glazes.

CHESTER HEIGHTS. CHESTER HEIGHTS QUARRY.

The Chester Heights quarry (72) is one-fourth mile west of the railroad station at Chester Heights and about 50 feet above the railroad.

The dike strikes northeast and dips southeast. It averages 20 feet in width and is exposed in the quarry for a distance of about 160 feet. A large proportion of the dike is an albite pegmatite, but toward the north end of the quarry this is displaced by a buff microcline pegmatite in which the quartz is of the smoky variety. In many places the dike contains streaks of chlorite, and the sorting of the feldspar must be conducted with care in order to eliminate this material and also to insure the complete separation of the buff microcline pegmatite and the white albite pegmatite. In the south end of the quarry the albite pegmatite is considerably altered, resulting in a kaolin-like material, but lacking in plasticity. Small quantities of cream and salmon microcline were noted, but not in commercial quantity. The various constituents of this dike are more or less segregated, thus simplifying quarrying, but the proportions of the different ingredients do not maintain sufficient uniformity to permit of a uniform material being obtained by taking the run of the quarry. The microcline and albite pegmatites were sampled and analyzed, showing the following chemical compositions:

Composition of microcline and of albite pegmatites from Chester Heights quarry.

	Microcline pegmatite.	Albite pegmatite.
Ignition loss .... per cent..	0. 33	0. 42
SiO_2 .... do....	73. 35	74. 60
Al_2O_3 .... do....	14. 60	15. 66
Fe_2O_3 .... do....	0. 06	0. 05
TiO_2 .... do....	......	......
CaO .... do....	0. 06	2. 75
MgO .... do....	......	......
Na_2O .... do....	2. 00	6. 33
K_2O .... do....	9. 11	0. 65
	99. 51	100. 46

The microcline pegmatite has a deformation range of 1,290° to 1,310° C. and fuses to semitransparent glass of a faint cream tint.

The albite pegmatite has a deformation range of 1,290° to 1,295° and fuses at 1,300° to a shapeless mass of white enamel.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

Microcline.—In the standard mixture the microcline pegmatite vitrifies at 1,300°, and at 1,330° C. does not show warping. Fired at 1,330° it has a total shrinkage of 11.8 per cent, a cream color, and a translucency of 0.86. The color is slightly inferior to that of the standard trial. It is not altered under the raw-lead and fritted glazes.

Albite.—In the standard porcelain mixture the albite pegmatite vitrifies at 1,300°, and at 1,330° shows slight warping. Fired at 1,330° it has a total shrinkage of 10.4 per cent, a cream color, and a translucency of 0.79. The color is a good white, but the porcelain is a characteristic soda-feldspar porcelain and lacks the brilliant fracture of the potash-feldspar porcelains. Under the raw-lead and fritted glazes the color is unaltered.

CHELSEA. BUNTING QUARRY.

Midway between Chelsea and Boothwyn station is the old Bunting quarry (73), which has been abandoned for many years. It is reported as having produced a high grade of potash feldspar, but the exposure shows only low-grade pegmatite.

BOOTHWYN. HALSEY QUARRY.

The Halsey quarry (74) is 1 mile northwest of Boothwyn station, on the west side of the Boothwyn-Chelsea road. This quarry has been worked intermittently for the past 15 years. It never has been a large producer, and the workings cover only an area of about 100 square yards. No work has been done here for several years. The dike consists of a coarsely crystalline pegmatite similar to the Chester Heights quarry. The clean buff pegmatite and pure feldspar has all been removed from the quarry, and only a small amount of mixed pegmatite and some albite pegmatite is in sight.

BOOTHWYN. BOOTHWYN QUARRY.

The Boothwyn quarry (75) is one-half mile west of Boothwyn village, on the Boudwin farm, on the east bank of Naaman Creek. The quarry is now filled with water and continuous pumping would be necessary if operations were resumed. In this quarry, which exposes a dike nearly 40 feet wide, the feldspar is a dark buff microcline pegmatite of which a great part is graphic granite. There is little mica and no black tourmaline present in any of the exposed faces or on the dump heaps. As the quarry was filled with water to a level with the creek bed, a thorough inspection was impossible.

Just west of the creek a small pit on a knoll has exposed a dike of albite pegmatite of good quality and apparently very free from impurity. The opening is, however, too small to prove anything beyond the presence of the albite pegmatite.

The buff microcline was tested and has a range of deformation of from 1,295° to 1,310° and fuses to a semitransparent glass of pale cream tint.

The albite pegmatite was tested and has a deformation range of 1,300° to 1,305° C., and fuses at 1,310° C. into a shapeless mass of opaque white enamel.

In the standard mixture the albite pegmatite vitrifies at 1,310° C. and no warping is noted at 1,330°. Fired at 1,330° it has a total shrinkage of 12.6 per cent and a cream translucency of 0.77. The color of the porcelain is good, but it lacks the brilliancy of fracture of the potash-feldspar porcelains.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

In the standard porcelain mixture the microcline vitrifies at 1,300°, and at 1,330° C. does not show warping. Fired at 1,330° C. it has a total shrinkage of 12.4 per cent, a cream color, and a translucency of 0.79. The color of the porcelain is not quite equal to that of the standard trial, but is fully up to commercial requirements. It is not altered under the raw-lead and fritted glazes.

ELAM. BRANDYWINE SUMMIT QUARRY.

The Brandywine Summit quarry[a] (76), at Elam, 1½ miles south of Brandywine Summit station, was the largest in Pennsylvania, covering about 4 acres and extending in some places to a depth of 100 feet. This quarry was worked for kaolin on the surface, but the lower levels were unweathered feldspar and were very coarsely crystallized with quartz, yielding a great amount of pure feldspar of a cream to flesh color. The main dike has now been worked out and abandoned and the pits and shafts are filled with water. No graphic granite was reported from the main quarry, but about 300 yards east of this a dike of graphic granite of good quality is being opened. This dike lies quite flat and carries a considerable content of weathered material, but this can easily be removed in quarrying. The more solid condition of the surface material would indicate that fresh feldspar in quantity may be looked for at less depth than in the original quarry. The dike now being worked is not so large as the one formerly worked and may be a stringer of that dike. The feldspar is a mixture of buff and cream microcline with intergrowths of albite and is not of sufficiently coarse crystallization to permit of the elimination of the quartz.

Numerous outcrops of feldspar and pegmatite are noted in the neighborhood, and doubtless this district is capable of producing much more feldspar, although another deposit as large as the original quarry is not looked for.

The graphic granite at the new opening was sampled and tested and shows a deformation range of 1,300° to 1,310° C. It fuses to a slightly milky glass with a faint cream tint.

[a] For a description of this deposit see Bastin, E. S., Economic geology of the feldspar deposits of the United States: Bull. 420, U. S. Geol. Survey, 1910, pp. 70–71.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

In the standard mixture this feldspar vitrifies at 1,310°, and at 1,330° shows no warpage. Fired at 1,330° it has a total shrinkage of 12 per cent, a cream color, and a translucency of 0.80. The color of the porcelain is hardly equal to that of the standard trial but is equal to that of the product of commercial feldspar. Under the raw-lead and fritted glazes the color is unaltered.

CHESTER COUNTY.

MENDENHALL. OLD WALKER QUARRY.

The old Walker quarry (77) is about 2 miles east of Mendenhall station. This quarry, which is now abandoned, is 120 feet long, 80 feet wide, and at least 50 feet deep, about 15 feet being under water. White albite pegmatite and a small amount of buff pegmatite show in the walls above the water line, and the dumps contain about equal proportions of these two pegmatites. This quarry is on the east side of the highway, which runs northeast at this point, and is about 40 feet below the floor of the new Walker quarry.

MENDENHALL. NEW WALKER QUARRY.

The new Walker quarry (78) is about 2 miles east of Mendenhall station and 300 yards southwest of the old Walker quarry. This quarry is on the west side of the highway, which runs through a ravine at this point, and is opened at a level about 50 feet above the road. It is in a dike about 25 feet wide which consists of a coarse mixture of pure buff microcline feldspar, buff microcline pegmatite, and white albite pegmatite. The strike follows the face of the hill and is northeast. The dip is about 40°. The upper strata are almost pure buff microcline, the middle strata are buff microcline pegmatite, and the lower strata are white albite pegmatite. The quartz in the pegmatites is clear, but the deposit contains many lenses of granular smoky quartz. Muscovite in large and small "books" is very common, and to insure its elimination careful sorting would be necessary. Very little biotite or garnet and no tourmaline were noted in this quarry, which when inspected was 25 feet deep and 50 feet long.

The buff microcline of the pegmatite and the pure buff feldspar were tested and found to possess the same physical properties. The pure buff microcline has the following composition.

Composition of pure buff microcline from new Walker quarry.

	Per cent.
Ignition loss	0.21
SiO_2	64.36
Al_2O_3	20.01
Fe_2O_3	.20
TiO_2	.....
CaO	.46
MgO	.....
Na_2O	2.48
K_2O	12.44
	100.16

It has a deformation range of 1,280° to 1,295° C. and fuses to a semitransparent glass free from tint.

The albite pegmatite was sampled and analyzed, showing a composition as follows:

Composition of albite pegmatite from new Walker quarry.

	Per cent.
Ignition loss	0.60
SiO_2	67.93
Al_2O_3	20.49
Fe_2O_3	.30
TiO_2	.....
CaO	2.60
MgO	.....
Na_2O	6.95
K_2O	.80
	99.67

It has a deformation range of 1,300° to 1,305° C. and at 1,310° C. is fused into a shapeless mass of white enamel.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

Microcline.—In the standard porcelain mixture the buff microcline feldspar vitrifies at 1,300° C. and at 1,330° shows no warpage. Fired at 1,330° C. the total shrinkage is 12.8 per cent, the color is cream white, and the translucency is 0.80. The color is about equal to that of the standard trial and is not altered under the raw-lead and fritted glazes.

Albite pegmatite.—In the standard porcelain mixture the albite pegmatite vitrifies at 1,310° and slightly warps at 1,330° C. Fired at 1,330° C. the porcelain has a total shrinkage of 11.8 per cent, a cream color by transmitted light, and a translucency of 0.80. It has a good white color but lacks the brilliancy of the potash feldspar porcelains. The color is not altered under the raw-lead and the fritted glazes.

EMBREEVILLE. EMBREEVILLE QUARRY.

The Embreeville quarry (79) is about 100 yards north of the depot at Embreeville. The dike[a] has been opened on a slight eminence and shows on both sides of the pit, which is about 15 feet

[a] For a description of this deposit see Bastin, E. S., Economic geology of the feldspar deposits of the United States: Bull. 420, U. S. Geol. Survey, 1910, p. 67.

deep and 30 feet in diameter. The feldspar of this dike is albite, occurring with quartz as a pegmatite. No microcline is exposed, and no work has been done here recently except some sampling which had apparently been done just prior to the inspection of this property.

This albite pegmatite has a deformation range of 1,280° to 1,285° C. and at 1,290° is fused to a shapeless mass of white enamel.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

In the standard porcelain mixture the albite pegmatite vitrifies at 1,290° and at 1,330° C. shows slight warping. Fired at 1,330° this porcelain has a total shrinkage of 12.2 per cent, a cream color by transmitted light, and a translucency of 0.78. The color is a good white, but the structure shows slight bloating. The raw-lead and fritted glazes do not alter the color of the ware.

NEW GARDEN. LAFFERTY QUARRY.

The Lafferty quarry (80) is 2 miles southeast of New Garden on the Wilmington Pike. The quarry is located within a few rods of the Maryland State line. The dike here is about 30 feet wide and has been exposed to a depth of about 20 feet and for a distance of about 40 feet. The chief constituent of the dike is a pegmatite consisting of light cream microcline and clear quartz, and generally occurring as a finely crystalline graphic granite. Insignificant amounts of albite pegmatite were noted along the walls. The quarry is remarkably free from biotite and garnets, a small amount of muscovite being the only associate mineral noted in the pegmatite. Numerous outcrops of similar microcline pegmatite were noted in the vicinity of this quarry.

The graphic granite in the quarry was sampled and is found by analysis to have the following chemical composition:

Composition of graphic granite from Lafferty quarry.

	Per cent.
Ignition loss	0.30
SiO_2	72.39
Al_2O_3	15.57
Fe_2O_3	.20
TiO_2	......
CaO	.13
MgO	......
Na_2O	2.27
K_2O	9.55
	100.41

It has a deformation range of 1,290° to 1,310° C. and fuses to a semitransparent mass with a faint cream tint.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

In the standard mixture the feldspar vitrifies at 1,300° C. and at 1,330° shows no warping. Fired at 1,330° C. the porcelain has a total shrinkage of 11.8 per cent, a cream white color, and a translucency of 0.78. The color of the porcelain is almost equal to that of the standard trial and does not alter under the raw-lead and fritted glazes.

POMEROY. MEREDITH QUARRY.

The Meredith quarry (81) is 1¼ miles northeast of Sadsburyville and 2½ miles north of Pomeroy. The deposit[a] is a dike of varying width, averaging about 15 feet. It is badly folded in places and the strike is uncertain, but has a general northeast direction; the dip is east. The feldspar content of this dike varies in color but is very uniform in physical properties. The upper part of the dike is chiefly a flesh-colored microcline graphic granite of very fine grain. The color of the feldspar fades with depth and becomes practically white. The quartz content of this graphic granite is colorless and perfectly transparent. At a depth of about 25 feet lenses of pure feldspar of a pale cream color were observed at several points in the quarry. At the time of visiting, the workings were about 200 by 60 feet and had a maximum depth of 35 feet. Biotite and tourmaline are extremely rare in this quarry. A green mica is the chief associate mineral and in a few places in the deposits is so abundant that its elimination is not practical. The quantity of feldspar rendered useless on account of the presence of this mica is, however, not sufficient to seriously interfere with mining. This quarry was formerly operated for pottery feldspar but for several years the entire output has been crushed and sold as poultry grit.

The graphic granite of this quarry was sampled and analyzed and shows the following chemical composition:

Composition of graphic granite from Meredith quarry.

	Per cent.
Ignition loss	0.24
SiO_2	67.87
Al_2O_3	17.82
Fe_2O_3	15
TiO_2	......
CaO	.12
MgO	......
Na_2O	3.33
K_2O	10.93
	100.46

This graphic granite has a deformation range of 1,285° to 1,300° C. and fuses to a glass which is almost transparent, and has only a faint cream tint.

[a] For a description of this deposit see Bastin, E. S., Economic geology of the feldspar deposits of the United States: Bull. 420, U. S. Geol. Survey, 1910, p. 67.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

In the standard mixture this feldspar vitrifies at 1,290° and at 1,330° C. no warping is apparent. Fired at 1,330° C. the total shrinkage is 11.6 per cent, the porcelain has a light cream color, and a translucency of 0.84.

The color of the porcelain is almost equal to that of the standard trial and is not altered under the raw-lead and the fritted glazes.

CHATHAM. CHATHAM QUARRY.

The Chatham quarry is three-fourths of a mile northeast of Chatham village. The deposit (82)[a] is a pegmatite of very irregular structure but containing chiefly a pale flesh-colored microcline intergrown with white quartz. Small flakes of muscovite and biotite are scattered through some parts of this dike, whereas other parts are practically free from mica. Much massive sugar quartz and very little of the albite pegmatite is noted. A pit approximately 100 by 100 feet and more than 40 feet deep has been opened, but the dike lies very flat here and the overburden increases so rapidly with depth that tunneling was resorted to in order to reduce mining expense. This also was found impracticable and operations have been suspended. Owing to the pit being partly filled with water a satisfactory sampling of this deposit was impossible. An average sample of the feldspar exposed in the walls and found in the dumps has a deformation range of 1,300° to 1,315° C. and fuses to a semitransparent glass free from tint.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

In the standard porcelain mixture this feldspar vitrifies at 1,310° C. and shows no warping at 1,330° C. Fired at 1,330° C. the porcelain has a total shrinkage of 12.6 per cent, a cream color by transmitted light, and a translucency of 0.79. The color of the porcelain is almost equal to that of the standard trial and is fully equal to that of commercial porcelain. It is not altered under the raw-lead and fritted glazes.

TOUGHKENAMON. JENKINS QUARRY.

The Jenkins quarry is $1\frac{1}{4}$ miles north of Toughkenamon. The deposit (83) is a dike which strikes east and west and dips southeast. The quarry is on a north slope and exposes the dike for a distance of about 50 feet. The feldspar is chiefly coarse buff and salmon microcline pegmatite, with a small quantity of white albite pegmatite. Very little massive quartz is noted. The chief impurities are the micas. The albite pegmatite contains small flakes both of muscovite and of biotite, whereas only muscovite is noted in the microcline pegmatite, and it is confined to limited zones. This quarry was inactive at the time of visiting. The microcline pegmatite was sampled and tested. It has a deformation range of 1,280° to 1,295° C. and fuses to a semitransparent mass with a faint yellow tint.

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[a] For a description of this deposit see Bastin, E. S., Economic geology of the feldspar deposits of the United States: Bull. 420, U. S. Geol. Survey, 1910, pp. 65-66.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

In the standard mixture the microcline pegmatite vitrifies at 1,290° C. and at 1,330°, no warping is apparent. Fired at 1,330° C. it has a total shrinkage of 11.2 per cent, a cream color, and a translucency of 0.85. The color of the porcelain is slightly inferior to that of the standard trial and is not altered by application of the raw-lead and fritted glazes.

TOUGHKENAMON. CARPENTER QUARRY.

The Carpenter quarry (84) is 1½ miles north of Toughkenamon and just west of the Jenkins quarry. The deposit[a] is a dike which at this point is about 30 feet wide and has a north and south strike. Numerous stringers from this dike have been located and the pegmatite removed from them. The main deposit and the adjacent stringers have been worked out for several years, and at present the operation consists of forking over the dump heaps from the original workings. In this way a considerable amount of marketable pegmatite is obtained. The pegmatite of the main dike is reported as being a very coarse mixture of microcline and quartz, but the few stringers exposed in this neighborhood indicate a fine-grained pegmatite, carrying a small amount of albite. Biotite is practically absent and muscovite is present chiefly as small flakes intimately intermixed in the pegmatite.

The microcline pegmatite was tested and found to have a deformation range of 1,275° to 1,290° C. and fuses to a semitransparent mass of a pronounced cream color.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

In the standard porcelain mixture the pegmatite vitrifies at 1,290° C. and at 1,330° C. shows no warping. Fired at 1,330° C. it has a total shrinkage of 11 per cent, a cream color by transmitted light, and a translucency of 0.75. The color of the porcelain is slightly inferior to that of the standard trial, and it is not altered under the raw-lead and fritted glazes.

BAKER. THOMPSON QUARRY.

The Thompson quarry[b] (85) is located three-quarters of a mile east of Baker station and 1½ miles northwest of Avondale. Operations here have been abandoned and no evidence of feldspathic material is visible, except small lumps of very clean microcline pegmatite in the dumps. This pegmatite is practically free from biotite and the muscovite present is confined to lumps of gneiss, which constitute a proportion of the dike about equal to that of the feldspar.

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[a] For a description of this deposit see Bastin, E. S., Economic geology of the United States: Bull. 420, U. S. Geol. Survey, 1910, p. 66.

[b] See Bastin, E. S., Op. cit., p. 65.

AVONDALE. HICKS QUARRY.

The Hicks quarry (86) is located 2 miles north of Avondale and almost due north of the Thompson quarry. Narrow dikes with a general north and south strike have been opened by shallow pits, showing a semiweathered albite pegmatite and a solid microcline pegmatite in about equal quantity. Only a few tons of material have been removed and no work was being done at the time of inspection. Both the albite and the microcline pegmatite are contaminated by small flakes of biotite, but the exposures are merely in the capping of the dikes and can not be taken as indicative of the composition of the dike at greater depths. The microcline pegmatite is composed of a mixture of buff and salmon feldspar and gray quartz, and a sample of this pegmatite was taken. It could not be cleaned of its biotite content but was tested for deformation range, which was found to be 1,285° to 1,290° C. The impurity present produces on fusion a yellow glass containing a large amount of undissolved biotite.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

In the standard mixture this pegmatite produces vitrification at 1,290° and at 1,330° C. shows no warpage. The total shrinkage is 11.2 per cent and the translucency is 0.59. The color of the porcelain is faulty, due to the biotite present in the ground feldspar.

BAKER STATION. FELDSPAR QUARRIES.

These quarries (87) are located on the property of the Pennsylvania Marble & Granite Co.[a] and on adjacent property [b] at Baker station. The deposit is a dike of varying width but never exceeding 25 feet and is composed of a fine-grained pegmatite intermixed with a gneiss in about equal parts. Both muscovite and biotite are present and render part of the pegmatite worthless. There are three openings but none of them have been operated for several years.

The feldspar content of the pegmatite is a cream microcline with intergrowths of albite in amount equal to the microcline. A considerable quantity of this pegmatite remains at the side of the largest pit, and this was sampled and tested. It has a deformation range of 1,270° to 1,280° and fuses to a semiopaque slightly creamy mass.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

In the standard mixture the above feldspar vitrifies at 1,280° C. and shows distinct warpage at 1,330° C. Fired at 1,330° C. the total shrinkage is 11.6 per cent, the translucency is 0.74, and the color is cream. The color of the porcelain is slightly inferior to that of the standard trial and is not altered by the raw-lead and the fritted glazes

[a] For a description of this deposit see Bastin, E. S., Economic geology of the feldspar deposits of the United States: Bull. 420, U. S. Geol. Survey, 1910, p. 64.

[b] See Bastin, E. S., Op. cit, p. 65.

AVONDALE. COOPER QUARRIES.

The Cooper quarries (88) are 1 mile southwest of New Garden post office and 1½ miles southeast of Avondale. Two quarries have been opened on the property about 400 yards apart. The structure is similar in these pits and as they are on the strike of the dike, which is north and south, they doubtless represent two lenses in the same dike. Both exposures show a pink microcline pegmatite containing smoky quartz and remarkably free from biotite or other iron-bearing impurity. Muscovite is present in very limited quantity. A white albite pegmatite is present but is confined to the regions along the walls of the dikes. The dike at both quarries is about 20 feet wide and has been opened for a distance of about 30 feet in each case. The south pit has been abandoned for some time and is partly filled by the caving of the walls. The north pit has been worked recently and much good feldspar is in sight. The pink microcline pegmatite of this pit was carefully sampled and tested. It has a deformation range of 1,280° to 1,295° and fuses to a semi-transparent glass of a faint cream color.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

In the standard porcelain mixture this pegmatite vitrifies at 1,290° C. and at 1,330° C. shows no warpage. Fired at 1,330° C. the total shrinkage is 12 per cent, the color is cream by transmitted light, and the translucency is 0.72. The color is slightly inferior to that of the standard trial and is unaltered under the raw-lead and fritted glazes.

SYLMAR. BRANDYWINE QUARRY.

A number of quarries,[a] of which the majority are now abandoned, are located within a radius of 2 miles west and north of Sylmar, Md., in Chester County, Pa., and Cecil County, Md. The largest quarry at present operating is the Brandywine quarry (89), 1 mile north of Sylmar station. It consists of numerous small pits on an irregular and extremely lenticular dike. The deposit has an entirely different structure from any other feldspar deposit thus far described. The mass of the dike is a coarsely crystalline albite, free from quartz and containing a few isolated crystals of muscovite and hornblende. The walls of the dike contain at frequent intervals narrow bands of a hydrated magnesium aluminum silicate. The dike here has a width of about 20 feet and has been in several places opened for a distance of about 100 feet. There is no variation with depth as is the case in most pegmatite dikes carrying potash feldspars, and quarrying has continued for a depth of 60 to 80 feet which in this narrow dike makes the problem one of shafting rather than quarrying. The albite

[a] For a description of these deposits see Bastin, E. S., Economic geology of the feldspar deposits of the United States: Bull. 420, U. S. Geol. Survey, 1910, pp. 68-70.

occurs in three forms—(*a*) as lenses of milk-white, massive rock of concoidal fracture, (*b*) as lenses of cream-colored rock of irregular fracture, and (*c*) as a granular gray rock consisting of semiopaque crystals of albite. The milk-white and the cream-colored rocks constitute the majority of the deposit. All these albites become pure white on calcining, which is a treatment to which all soda feldspar is subjected before grinding.

The milk-white and cream albite was carefully sampled and analyzed, showing the following chemical composition:

Composition of albite from Brandywine quarry.

	Per cent.
Ignition loss	0.83
SiO_2	67.47
Al_2O_3	20.05
Fe_2O_3	.15
TiO_2	
CaO	.24
MgO	
Na_2O	9.74
K_2O	.86
	99.34

This albite has a deformation range of 1,270° to 1,280° C. and fuses to a semitransparent glass free from tint at 1,290° C.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

In the standard porcelain mixture this feldspar vitrifies at 1,280° and at 1,330° C. produces slight warpage. Fired at 1,330° C. the total shrinkage is 12 per cent, the translucency is 0.82, and the color is cream white. The porcelain is almost equal to the standard trial as regards color, but on being struck it gives off a dull sound typical of soda feldspar porcelains.

The magnesium aluminum silicate which occurs along the walls of this dike has the following composition:

Composition of magnesium aluminum silicate.

	Per cent.
Ignition loss	17.30
SiO_2	45.46
Al_2O_3	13.40
Fe_2O_3	.05
TiO_2	.04
CaO	.08
MgO	23.28
Na_2O	.16
K_2O	.30
	100.07

This mineral is crystalline in character and on calcination becomes a pure white. That it has been employed to some extent or at least not eliminated from the albite in the sorting process is evidenced by the fact that analysis of the commercial feldspars of this region invariably show a content of MgO, which according to the analysis given above is not present in either the milk-white or cream albite of this district.

SYLMAR. NEW BRANDYWINE QUARRY.

About one-half mile southwest of quarry (89), the same company has just opened a new quarry (90) on a number of small stringers of the main deposits which are one-fourth mile west. These stringers are only 6 to 10 feet wide where opened, but may expand toward the west. Only the surface has been removed but the material exposed appears similar in every way to that of the formation described above.

SYLMAR. OLD BRANDYWINE QUARRY.

The old Brandywine quarry (91) one-fourth mile west of quarry (90) of this company and 1½ miles by road northwest of Sylmar. This quarry, which is now abandoned and is reported as exhausted, was an enormous lens of albite similar to that found in the smaller dikes now being worked to the east of this quarry. Bastin[a] describes this deposit as a single dike striking northwest and exposed for a distance of 200 feet to a depth of about 80 feet. The dike expands from a width of 12 feet at the south end to about 80 feet at the north end. The wall rock is serpentine with a band of blue-green slate about 1 foot thick along the wall contacts. This quarry was entirely filled with water and no inspection was possible.

SYLMAR. OLD KEYSTONE QUARRY.

The old Keystone quarry (92) is about one-half mile south of the old Brandywine quarry and almost due west from Sylmar station. This quarry is abandoned; the deposit, reported to be exhausted, was an enormous lens similar in all respects to the old Brandywine quarry. The pit, which was reported to be filled with water to depth of 80 feet, is approximately 400 feet long and 150 feet wide. The feldspar mined is reported as similar to that mined in the Brandywine quarry.

SYLMAR. OLD SPARVETTA QUARRY.

The old Sparvetta quarry is located about 300 yards northwest of the old Keystone quarry on what was doubtless the same dike but another lens. The pit, which has filled with water, has a surface area of 500 feet by 150 feet. This quarry produced an enormous quantity of albite of a quality not differing widely from that obtained from the other quarries in the immediate neighborhood.

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[a] Bastin, E. S., Economic geology of the feldspar deposits of the United States: Bull. 420, U. S. Geol. Survey, 1910, p. 69.

MARYLAND.

CECIL COUNTY.

CONOWINGO. ROCK SPRING QUARRY.

The Rock Spring quarry (93), is about 3½ miles northeast of Conowingo, near the village of Rock Springs. This quarry was reported by Bastin [a] as a small operation and has now been abandoned for several years. No evidence of commercial feldspar is to be seen, as the pit has filled by cavings from the walls, thus covering the walls. The feldspar mined was a fine grade of albite, but the quantity obtained is reported too small to justify operations.

CONOWINGO. BALD FRIAR QUARRY.

The Bald Friar quarry (94) is located on a steep bluff on the east side of the Susquehanna River at Bald Friar, 1½ miles north of Conowingo. The feldspar occurs here in a series of sharply defined dikes 6 to 12 feet wide and varying from 25 to 100 feet long. The dike material is chiefly talc, with small lenses of pure white albite of excellent quality occurring at frequent intervals. No quartz, mica, or hornblende was encountered in mining this material. The talc has been exhausted, and the small amount of feldspar still exposed would not justify mining.

This feldspar was tested and found to have a deformation range of 1,270° to 1,280° C. At fuses at 1,290° C. to a semitransparent mass free from tint.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

In the standard porcelain mixture this albite vitrifies at 1,280° C., and at 1,330° C. shows slight warpage. Fired at 1,330° C. the total shrinkage is 12.4 per cent and the color is cream white and the translucency is 0.82. The color of the porcelain is excellent, but the structure is distinctly vesicular and the absence of the potash feldspar is evident.

BALTIMORE COUNTY.

GRANITE. GIFFORD QUARRY.

The Gifford quarry (99) is located on the south side of the branch of the Baltimore & Ohio Railroad which runs to Granite, and is 1 mile from the main line. The quarry is in a dike about 30 feet wide, which is composed of a mixture of buff and pale cream pegmatite. Both are microcline pegmatites but the buff is present in by far the largest quantity. A small amount of salmon microcline pegmatite is also observed, but does not constitute an important proportion of the output. The only associate minerals are muscovite and biotite, which are present in small flakes and in small amount only. Most of the mica can be removed by careful sorting.

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[a] Bastin, E. S., Economic geology of the feldspar deposits of the United States: Bull. 420, U. S. Geol. Survey, 1910, pp. 76–77.

GRANITE. PEACH QUARRY.

The Peach quarry (100) is on the north side of the branch of the Baltimore & Ohio Railroad leading to Granite, and one-half mile from the main line. This quarry is in a dike very similar to that in which the Gifford quarry is opened. A small amount of muscovite and biotite are noted but no large crystals of either are exposed in this quarry. Numerous small dikes or stringers from the main dikes of the Peach and Gifford quarries have been worked for pegmatite in this immediate vicinity and a product similar to that of the main dikes is obtained. The two large quarries were the only ones operating at the time of visiting.

A sample which is representative of the pegmatite of the dikes along the Granite branch of the Baltimore & Ohio Railroad shows a deformation range of 1,290° to 1,310° C. and fuses to a semitransparent glass with a faint cream tint.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

In the standard porcelain mixture, this pegmatite vitrifies at 1,300° C. and at 1,330° C. shows no warpage. Fired at 1,330° C. it has a total shrinkage of 13.2 per cent, a cream color by transmitted light, and a translucency of 0.79. The color of the porcelain is slightly creamy as compared with that of the standard trial, and is not affected by the raw lead and fritted glazes.

DAVIS. DIETZ QUARRY.

The Dietz quarry (102) is one-half mile east of Davis and 150 yards north of the railroad, between Davis and Dorseys Run. This quarry is newly opened, and at the time the writer visited it only the surface material had been removed. The dike, which is about 30 feet wide; was exposed for about 50 feet along the strike, which is northeast. The dike material is chiefly a buff microline pegmatite with minor quantities of albite pegmatite. The associated minerals are massive quartz, in very small amount, and muscovite, also in very small amount only. Biotite or other iron-bearing minerals have not been exposed in sufficient quantity to make their removal a serious problem.

The buff microcline pegmatite was sampled and tested. It has a deformation range of 1,275° to 1,290° C. and fuses to a pale cream glass which is semitransparent.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

In the standard porcelain mixture this pegmatite vitrifies at 1,280° C. and at 1,330° C. shows slight warpage. Fired at 1,330° C. the porcelain has a total shrinkage of 12.4 per cent, a cream color by transmitted light, and a translucency of 0.83. The porcelain shows a slight cream tint in comparison with the standard trial, but this is not intensified by the application of either the raw-lead or the fritted glaze.

ILCHESTER. ILCHESTER QUARRY.

The Ilchester quarry (104) is located on the hill opposite Ilchester. The deposit is a weathered dike in which one of the constituents, a dark buff microcline pegmatite, has withstood the disintegrating action. The rest of the dike has been reduced to a coarse sand, and the solid part is separated by forking or by screening the dike material. There are a number of these dikes in this vicinity, and they all strike northeast. The solid pegmatite is only found in the upper parts of the dike, the material below a depth of 7 feet being completely weathered.

Small flakes of muscovite and biotite are scattered through the pegmatite, but not in large amount. The dark buff pegmatite was tested and found to have a deformation range of 1,290° to 1,305° C. It fuses to a yellow glass which is semitransparent.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

In the standard porcelain mixture this pegmatite vitrifies at 1,300° C. and at 1,330° C. shows slight warping. Fired at 1,330° C. the porcelain has a total shrinkage of 13 per cent, a pronounced yellow color, and a translucency of 0.74. The color of the porcelain is a pronounced cream and becomes yellow under the raw-lead and the fritted glazes.

HOWARD COUNTY.

MARRIOTTSVILLE. ZEPP QUARRY.

The Zepp quarry (95) is one-half mile south of the depot at Marriottsville. This quarry is in a dike, the width of which could not be determined, but from indications is not less than 50 feet. It has been proved for a distance of one-half mile north and prospect pits indicate the presence of what is probably the same dike about one-half mile south.

This quarry was just opened at the time of inspection and much surface material was still to be removed before the extent of the deposit would be exposed. The rock uncovered is a light cream pegmatite, chiefly microcline and quartz, with small intergrowths of albite. Biotite is observed, but this can be removed by careful sorting at the quarry.

MARRIOTTSVILLE. WARFIELD QUARRY.

The Warfield quarry (96) adjoins the Zepp quarry on the north and is on the same dike. This quarry has been opened longer and a better opportunity to study and sample the deposit was afforded. The dike, which was exposed for a distance of 100 feet and a width of about 30 feet, extends under the highway; hence the full width can not be worked. The dip follows the slope of the hillside and is northwest. The feldspar is a cream-colored microline pegmatite, with which is associated a small amount of albite. This dike contains very little biotite, but a band of sandstone and a narrow band of limestone show in the quarry. The limestone and sandstone are easily removed, however, and need cause no contamination in mining. Massive quartz is not encountered in any quantity in this dike so far as exposed.

The pegmatite in this dike was sampled and analysis shows the composition to be as follows:

Composition of pegmatite from Warfield quarry.

	Per cent.
Ignition loss	0.39
SiO_2	65.83
Al_2O_3	19.48
Fe_2O_3	.20
TiO_2	.00
CaO	.00
MgO	.00
Na_2O	1.87
K_2O	11.33
	99.10

This feldspar has a deformation range of 1,295° to 1,310° C. and fuses to a semitransparent glass with a pale cream tint.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

In the standard porcelain mixture this feldspar vitrifies at 1,300° C. and at 1,330° C. shows no evidence of fusion. Fired at 1,330° C. it has a total shrinkage of 12.2 per cent, a cream color by transmitted light, and a translucency of 0.80.

The color of the porcelain is slightly more creamy than that of the standard trial and does not alter under the raw lead and fritted glazes.

MARRIOTTSVILLE. OLD WARFIELD QUARRY.

The Old Warfield quarry (97) is due north from the new Warfield quarry, but is on the opposite side of the creek. This quarry was a good producer of pegmatite similar to that of the new quarry and an opening 30 feet wide and 20 feet deep has been made. The overburden is much heavier than in the new workings and the quarry has been temporarily abandoned in favor of the new quarry, which has only a thin overburden.

MARRIOTTSVILLE. BAKER QUARRY.

The Baker quarry (98), is one-fourth mile east of the depot at Marriottsville, and is located on a steep slope on the south side of the railroad. The opening is about 20 feet in diameter and varies from 5 to 10 feet in depth. The pegmatite exposed is similar to that of the Zepp and Warfield quarries. The only iron-bearing impurity in the pegmatite is a small quantity of biotite which could easily be eliminated without serious loss of feldspar.

MARRIOTTSVILLE. FRENCH QUARRY.

Located about 1 mile northeast of Marriottsville is a small quarry similar to the others in this neighborhood. In this quarry, however, a considerable amount of graphic granite is exposed. Muscovite is practically absent and biotite is present only in very small quantity. This quarry has not been operated for some time, but the deposit is not exhausted.

WOODSTOCK. CAVEY QUARRY.

The Cavey quarry (101) is three-fourths mile south of Woodstock. This quarry exposes two dikes; one is a light buff pegmatite dike of very solid structure, and the other, at least as far as opened, is a mixture of fresh and weathered pegmatite, and to the casual observer would resemble a gravel bank, as in the mining the solid feldspar is separated from the weathered material by means of a fork similar to that used in handling coal. The quarry in the solid dike, which is 15 feet wide and is almost vertical, is about 30 feet long and 12 feet deep. The dike consists of a light buff microline pegmatite associated with a friable white albite pegmatite. The chief associate minerals are muscovite and biotite, small flakes of which are scattered through the pegmatite. To separate these minerals from the feldspar would be extremely difficult owing to the small size of the flakes. The amount present, however, is so small that it does not constitute a menace to the feldspar being successfully used for pottery manufacture.

These pegmatites were sampled separately and analyzed, showing the following chemical compositions:

Composition of microcline and albite pegmatite from Cavey quarry.

		Microcline pegmatite.	Albite pegmatite.
Ignition loss	per cent	0.13	0.76
SiO_2	do	74.20	65.32
Al_2O_3	do	14.30	22.00
Fe_2O_3	do	.20	.21
TiO_2	do	.00	.00
CaO	do	.00	3.78
MgO	do	.00	.00
Na_2O	do	1.59	6.89
K_2O	do	9.48	1.06
		99.90	100.02

This microcline pegmatite has a deformation range of 1,295° to 1,310° C. and fuses to a pale cream semitransparent glass.

The albite pegmatite has a deformation range from 1,310° C. to 1,315° C. and at 1,320° becomes a shapeless mass of white enamel.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

Microcline pegmatite.—In the standard porcelain mixture this microcline pegmatite vitrifies at 1,300° C. and at 1,330° C. shows no warpage. Fired at 1,330° C. the porcelain has a total shrinkage of 13 per cent, a cream color, and a translucency of 0.84. The color is slightly more creamy than that of the standard trial and is unaltered under the raw-lead and the fritted glazes.

Albite pegmatite.—In the standard porcelain mixture the albite pegmatite virtifies at 1,330° C. and at 1,330° C. shows slight warpage. Fired at 1,330° C. the porcelain has a total shrinkage of 11.2 per cent and a cream color by transmitted light translucency of 0.72. The color of the porcelain is a very pale cream, and it is not altered under the raw-lead and fritted glazes.

The weathered dike produces a dark buff microcline of good quality, but the dike is narrow, and the operator stated that it only continues to a depth of 5 to 7 feet, below which it becomes too impure to justify mining.

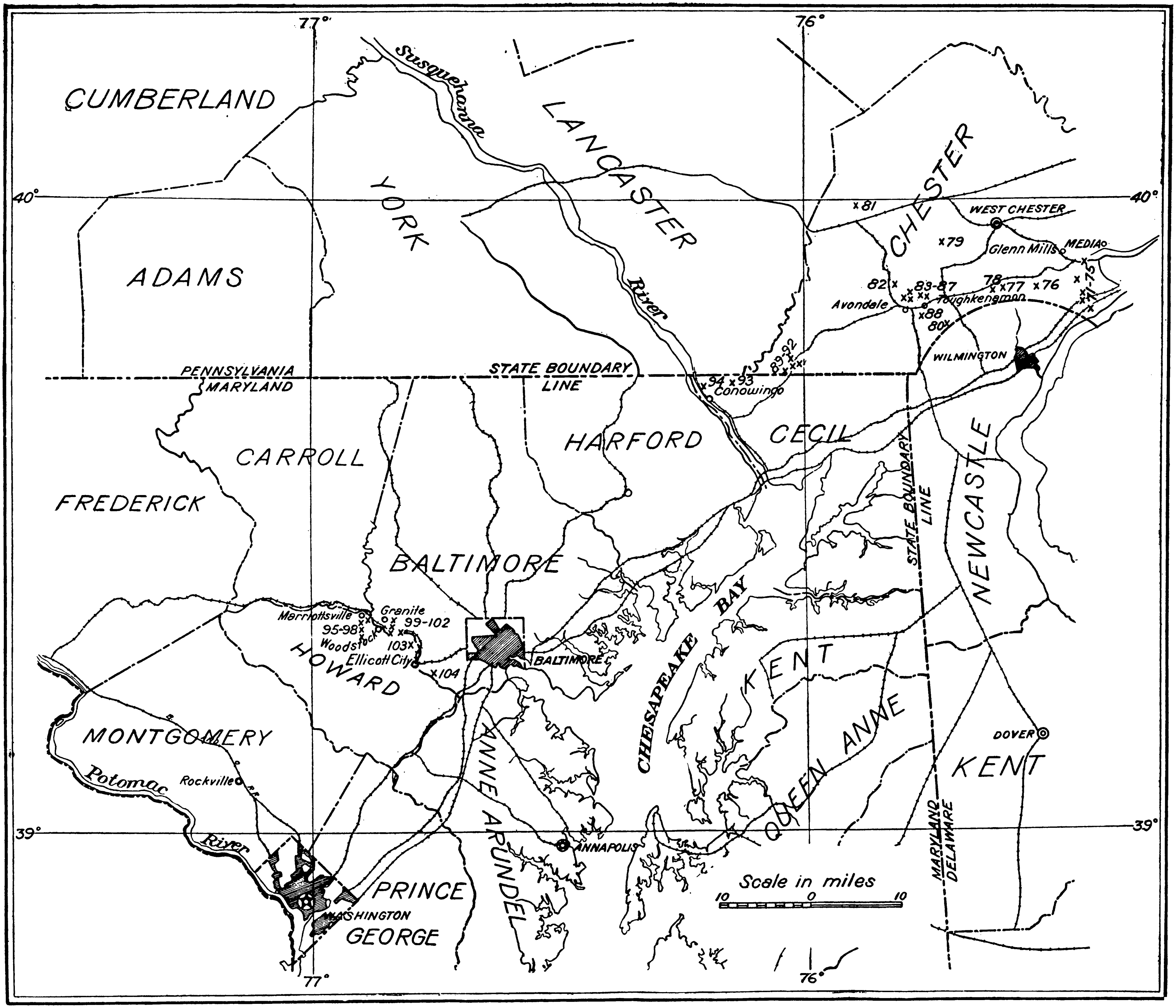
ALBERTON. ALBERTON QUARRY.

The Alberton quarry (103) is located on a north slope one-half mile south of Alberton. The quarry consists of a shallow pit about 15 feet wide and 50 feet long extending along the face of the hill. The dike material is a buff microcline pegmatite of medium coarse crystallization, with a few lenses of pure feldspar. Muscovite is present in limited zones but not in sizes to make it a marketable product. Biotite is present also, but in small amount. The quarry has only been opened a short time, and the full extent of the deposit is doubtless not exposed. White albite pegmatite is present in such small amount in the present opening as to be negligible.

The buff microcline pegmatite was sampled and tested. It has a deformation range of from 1,285° to 1,300° C. and fuses to a semitransparent glass with a faint cream tint.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

In the standard porcelain mixture this pegmatite vitrifies at 1,290° C. and at 1,330° C. shows no warpage. Fired at 1,330° C., the porcelain has a total shrinkage of 12.2 per cent, a cream color, and a translucency of 0.76. The color is light cream and is not altered under the raw-lead and fritted glazes.



SKETCH MAP OF PARTS OF PENNSYLVANIA AND MARYLAND, SHOWING FELDSPAR DEPOSITS INVESTIGATED. FOR DESCRIPTION OF DEPOSITS SEE TABLE 2.

VIRGINIA.

BEDFORD COUNTY.

LOWRY. M'NICHOLS QUARRY.

The McNichols quarry (105) is located on the Thompson place, 5 miles south of Lowry station, on the east bank of Otter River. There are two dikes exposed on the west slope of a ridge that runs north and south. The dikes' strike is northeast, the dip 75° N. The south dike, where exposed, is about 20 feet wide. In the middle is a band of pure feldspar, varying from 5 to 7 feet wide, with pegmatite on each side. This pegmatite, however, is rich in feldspar, and if care were exercised to eliminate the mica scattered through it much marketable feldspar could be obtained. This dike is opened 25 feet into the hill, being exposed for a depth of 40 feet and across its full width. The north dike, which is separated from the south one by about 30 feet of country rock, shows no band of pure feldspar, but is very rich in feldspar throughout its width of about 10 feet. This pegmatite is very coarsely crystalline and has considerable coarse muscovite scattered through it. Very little material has been removed from this part.

Another exposure of what is probably one of the same dikes is about 150 yards northeast, where pegmatite is exposed for a distance of over 50 feet. This area has not been opened, and the capping material shows muscovite and some biotite. Small lenses of pure muscovite and albite are noted at frequent intervals.

Feldspar from the south dike was analyzed and shows the following chemical composition:

Composition of feldspar from south dike.

	Per cent.
H_2O	0.10
SiO_2	68.75
Al_2O_3	18.56
Fe_2O_3	.03
TiO_2	Trace.
CaO	1.25
MgO	Trace.
K_2O	6.85
Na_2O	4.29
	99.83

The deformation temperature ranges from 1,260° to 1,265° C. The fused feldspar forms an opaque white mass.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

This feldspar in the standard mixture vitrifies at 1,265° C., and at 1,350° C. shows slight warping. The porcelain shows a very faint bluish tint. Fired at 1,350° C. this feldspar has a translucency of 0.64 and is cream colored by transmitted light. The total shrinkage is 15 per cent, the drying shrinkage being 3 per cent and the firing shrinkage 12 per cent. Under the raw lead and fritted glazes the color is unaltered.

NELSON COUNTY.

ARRINGTON. AMERICAN RUTILE QUARRY.

The American rutile quarry (106) is 8 miles northwest of Arrington, near Roseland post office. The quarry is in a dike about 75 feet wide, which has a northeast strike and is vertical. The dike is divided into two distinct sections by a vertical band of trap rock about 20 feet wide. South of this band the dike consists of a plagioclase carrying a high content of rutile and ilmenite. This part of the deposit is worked and the rutile extracted by means of jigs. No attempt to completely extract the ilmenite is made and a considerable amount of rutile remains in the tailings. Many lenses of albite free from rutile and other minerals are noted in this part of the dike but no attempt to save the albïte is made, as the haul is too far to make marketing it profitable.

The part north of the trap rock band is similar to the south part, except that hornblende has replaced the other minerals to a considerable extent. If transportation facilities are provided for the development of this property, the associated minerals can doubtless be eliminated from this feldspar and the latter made marketable. The run of the tailings from the south part of the dike has a deformation range of 1,310° to 1,320° C. and fuses to a yellow brown glass.

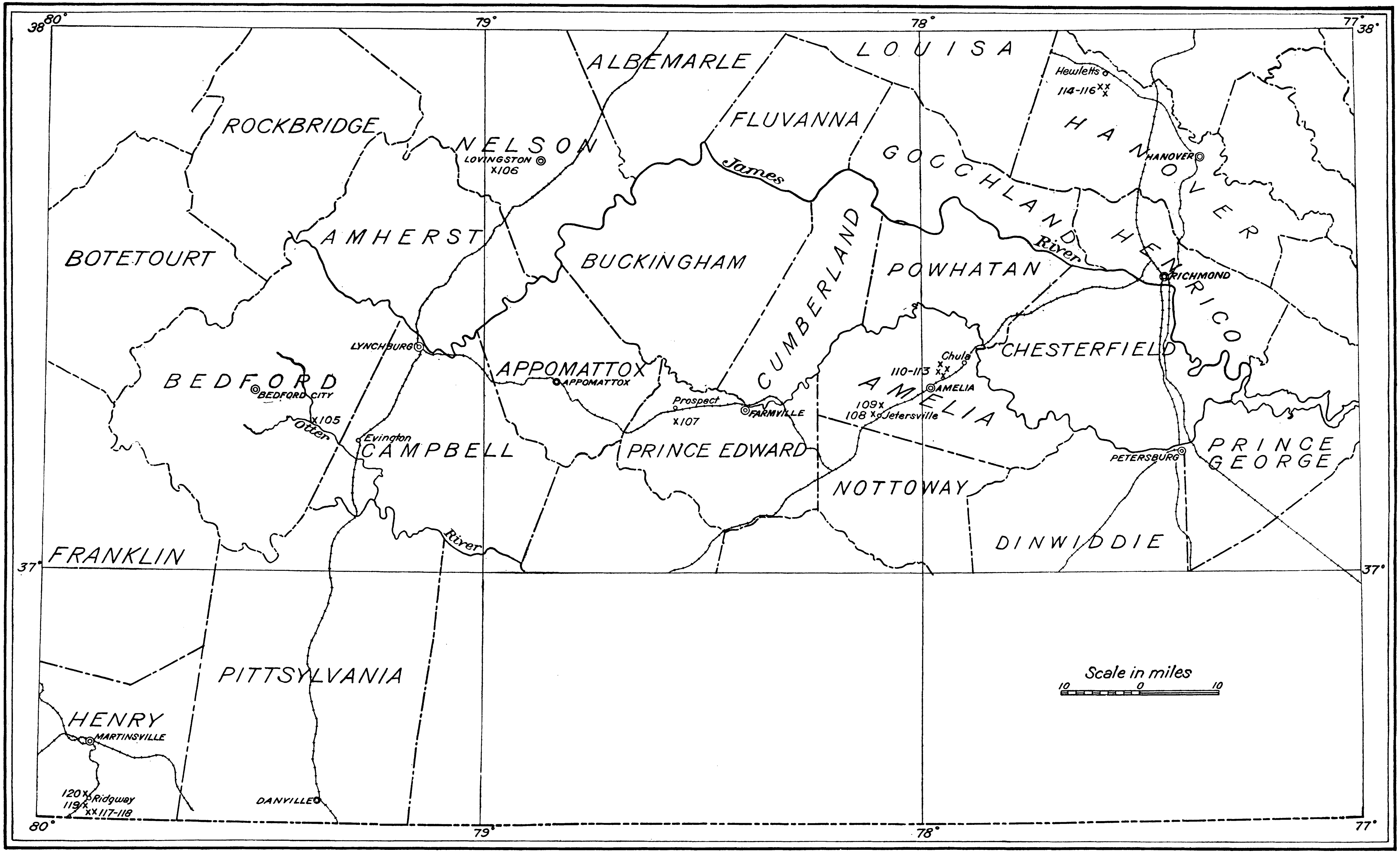
PRINCE EDWARD COUNTY.

PROSPECT. PROSPECT QUARRY.

The Prospect quarry (107) is one-half mile south of the village of Prospect. Two dikes have been opened on this property. One has a width of about 20 feet and has been quarried for a distance of 40 feet and to a depth of 15 feet. The other is about 12 feet wide and has been quarried for a distance of 30 feet and to a depth of about 12 feet. A large part of these dikes is a light cream pegmatite containing an excessive amount of quartz and also a large amount of muscovite distributed throughout the mass as small flakes. This part of the dike is, therefore, of doubtful value for pottery feldspar. Lenses of buff microcline pegmatite and lenses of pure buff microcline are present in large amount in both dikes. In the large dike one lens 8 feet wide is exposed. This buff microcline and pegmatite is very low in muscovite content and the pegmatite is low in quartz. No biotite is observed in either of the dikes, and other iron-bearing minerals are absent also. Operations on this property have been intermittent and the quarry was idle at the time of inspection. The dikes have not been exhausted, however.

The buff microcline and pegmatite were sampled to obtain an average of the run of the quarry and this was found to have a deformation range of 1,295° to 1,310° C. It fuses to a pale cream semitransparent glass.

166A



SKETCH MAP OF PART OF VIRGINIA, SHOWING FELDSPAR DEPOSITS INVESTIGATED. FOR DESCRIPTION OF DEPOSITS SEE TABLE 2.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

In the standard porcelain mixture this material vitrifies at 1,300° C., and at 1,330° C. no warpage is apparent. Fired at 1,330° C. this porcelain has a total shrinkage of 13.4 per cent, a cream color by transmitted light, and a translucency of 0.74. The color is slightly cream when compared with that of the standard trial, and is unaltered under the raw-lead and the fritted glazes.

AMELIA COUNTY.

JETERSVILLE. OLD SCHLEGEL QUARRY.

The old Schlegel quarry (108) is 1¼ miles northwest of Jetersville. This quarry was opened on a lens of a dike which can be traced for at least one-half mile northeast along the strike. The quarry has a width of about 20 feet and a length of about 40 feet. The workings have caved so that both the walls and the floor are obscured but a narrow face of wall was cleared along the strike and a cream microcline exposed which is free from quartz or other associated impurity. A large quantity of this class of feldspar is reported as being quarried here but a coarse pegmatite constitutes a considerable part of the dike. Numerous small dikes or stringers are noted throughout this country but no attempts have been made to prospect these.

The feldspar samples taken from the old Schlegel quarry were tested and found to have a deformation range of 1,295° to 1,310° C. and fuses to a semitransparent glass free from tint.

PROPERTIES IN STANDARD PORCELAIN MIXTURE

In the standard porcelain mixture this feldspar vitrifies at 1,300° C., and at 1,330° C. shows no warpage. Fired at 1,330° C. the porcelain has a total shrinkage of 13 per cent, a cream-white color by transmitted light, and a translucency of 0.82. The color of the porcelain is equal to that of the standard trial and is not altered under either the raw-lead or the fritted glaze.

An exposure of pegmatite (109) about 20 feet high occurs at Jetersville pond, 2 miles northeast of Jetersville, where the Jetersville-Painesville road crosses Flat Creek.

AMELIA. RUTHERFORD MICA MINE.

The Rutherford mica mine (110) is located 2 miles northeast of Amelia courthouse. The dike here is not exposed as the workings, which consisted of a number of shafts, have filled with water and have caved in many places. The width covered by shafts appears to be about 12 feet and the shafts continued along the strike for about 75 feet. There was no attempt at feldspar mining, so far as could be learned, but the dumps about the shafts contain large quantities of a semitransparent albite of exceptionally fine color, and a brilliant green microcline. Small "books" of a clear muscovite are also plentiful. Quartz is present only in the massive form. The albite appears to constitute the major part of the dike. An average sample of this shows a deformation range of 1,270° to 1,280° C. and at 1,290° C. fuses to a semitransparent glass free from tint.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

In the standard porcelain mixture this albite vitrifies at 1,280° C., and at 1,330° C. shows warping. Fired at 1,330° C. this porcelain has a total shrinkage of 12.8 per cent, a cream color by transmitted light, and a translucency of 0.86. The porcelain has a good color but lacks the brilliancy of the potash feldspar porcelain and shows a slightly vesicular structure. The color is not altered under the raw-lead and fritted glazes.

The green microcline is in sharply defined crystals but not in quantity to be economically important. An average sample of this microcline shows a deformation range from 1,280° to 1,295° C. and fuses to a semitransparent mass free from tint.

AMELIA. PINCHBACK MICA MINES.

The Pinchback mica mines (111, 112), which were apparently open pits, are scattered over an area of several acres just north of the Rutherford mine. These pits have all been filled by caving of the walls and by surface material draining into them. No refuse from the workings is exposed in dumps except a small amount of scrap mica. The latter is doubtless scrap or trimmings from the block mica as it is a considerable distance from the pits. No feldspar or quartz is found in the neighborhood of any of the shafts.

AMELIA. OLD CHAMPION MICA MINE.

The old Champion mica mine (113) is 3 miles northeast of the courthouse at Amelia and is east of the Pinchback mines. The dike is reported to be about 12 feet wide and has a general north and south strike and is nearly vertical. This mine was abandoned and allowed to fill with water, but at the time of inspection had been almost completely unwatered, as the mining of mica was to be resumed. The dike, as exposed in the walls of the shaft for a depth of 105 feet, is a coarse mixture of albite pegmatite and gray semiopaque quartz. The albite pegmatite averages about 5 feet wide and the quartz constitutes the remainder of the dike, which was intruded into a biotite gneiss. The muscovite, for which the mine was worked, occurs along the contact of quartz and pegmatite and along the contact of the pegmatite and wall. With the methods of mining practiced here, little of the feldspar will be removed.

The albite was sampled and tested. It has a deformation range of 1,300° to 1,305° C. and at 1,310° C. is completely fused. The presence of considerable calcium is indicated by the high deformation temperature and the rapidity of fusion. The opaque enamellike appearance of the fused feldspar also indicates a high calcium content.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

In the standard porcelain mixture this feldspar vitrifies at 1,300° C. and at 1,330° C. shows warping. Fired at 1,330° C. the porcelain has a total shrinkage of 12 per cent, a cream-white color by transmitted light, and a translucency of 0.87. The color of the porcelain is an excellent white, but the texture is vesicular. The color, however, is not affected by the raw lead and fritted glazes.

HANOVER COUNTY.

HEWLETTS. HEWLETTS MICA MINE.

The Hewletts mica mines (114, 115, 116) are 2 miles southeast of Hewletts and 1 mile north of the Washington-Richmond highway. Three quarries were opened on this property about 1870, but the mining was for mica and only such other material was removed as was necessary. The method of mining was by deep open cuts and these are reported to be 50 feet deep in places. Most of the cuts are about 100 feet long and about 8 feet wide. They were partly filled with water and thus an examination was made very difficult. The feldspar present is an albite of remarkable clearness and pronounced crystallization; associated with this is massive quartz, in quantity, which is clear and remarkably free from granulation. No iron-bearing minerals were observed on the dumps or associated with the feldspar and quartz in the exposed parts of the dike. The albite was sampled and tested. It has a deformation range of 1,305° to 1,310° C. and at 1,315° C. is completely fused, forming a white enamellike mass. This albite apparently has a considerable calcium content, as indicated by its high deformation temperature and short range.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

In the standard porcelain mixture this feldspar vitrifies at 1,310° C. and at 1,330° C. shows slight warpage. Fired at 1,330° C. the porcelain has a total shrinkage of 11.8 per cent, a cream-white color by transmitted light, and a translucency of 0.75. The color of the porcelain is good, but it has that texture characteristic of soda feldspar porcelains.

HENRY COUNTY.

RIDGEWAY. FELDSPAR DEPOSITS.

All these deposits lie within 2 miles, south and west, of Ridgeway. The feldspar is exposed in a number of places and shows evidence of being present in large quantities. It occurs in pegmatite that varies in fineness of structure, the feldspar content being chiefly cream microcline and ivory albite, associated with gray quartz and pale-green to rum-colored muscovite. Some white sugar quartz is present but in smaller amount than at points farther south. The country rock is chiefly gneiss. The dikes throughout the district have a general northeast strike.

One irregular exposure (117) in the bed of Matrimony Creek, near an old mill on the property of J. P. Garrett, has a breadth across the dike of at least 40 feet. The feldspar-bearing pegmatite is massive in some places and in others is fine grained with much fine mica. The creek flows between high hills and unless the feldspar can be found farther up the hillsides the cost of mining will be excessive because of overburden, except in the bed of the creek, where the problem of handling water would be serious. The deposit is about 2 miles south of Ridgeway and about 1 mile from the railroad.

On the same property, about one-half mile east of 117 in a road is an outcrop (118) of fine-grained pegmatite containing considerable fine mica considerably weathered. The indications are not very encouraging, but more prospecting should be done before any definite statement, regarding either quality or quantity, is made. This exposure is about 2 miles from Ridgeway and about 1 mile from the railroad.

On the same property, about one-half mile northwest of 117 in the bend of a road on a ridge a dike (119) is exposed that is about 50 feet wide but contains a number of bands of gneiss. Both feldspar and gneiss are much weathered in places. Several smaller dikes of completely kaolinized material have been exposed on this same ridge. This deposit is about three-quarters of a mile from the railroad, with a downhill haul.

About one-half mile to the northeast of 117 on the north slope of a ridge, running east-northeast, an extensive deposit of pegmatite has been exposed, either a large dike, containing several bands of included gneiss, or a series of narrower parallel dikes. The exposure has a total width of almost 100 feet and has been proven for a length of 250 feet. The pegmatite exposed is very coarse, containing much massive feldspar. The overburden varies from 5 to 10 feet. This deposit is one-half mile from the railroad, which is reached by a comparatively level haul. It was worked about five years ago and a few carloads shipped for grinding. Difficulties in marketing caused a shutdown.

The deposits on this property were all sampled and tested with the following results:

The feldspar from deposit 117 is a cream microcline pegmatite with intergrowths of albite. Its deformation range is 1,290° to 1,300° C. and it fuses to an excellent white enamel.

The feldspar from deposit No. 118 could not be obtained in sufficient purity to make a satisfactory test.

The feldspar from No. 119 is a cream-colored microline, free from any associated material, except quartz, and muscovite, the latter in small amounts only. It has a deformation range of 1,310° to 1,330° C. and an excellent color.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

In the standard porcelain mixture this feldspar produces vitrification at 1,300° C., and at 1,330° C. shows no warping. Fired at 1,300° C., it has a total shrinkage of 14.5 per cent and a cream white translucency of 70. The color is not altered by either the raw lead or fritted glaze.

The feldspar from deposit No. 120 is a cream microline similar to that from No. 119, but having a deformation range of 1,305° to 1,330° C. The color is excellent.

PROPERTIES IN STANDARD PORCELAIN MIXTURE.

Introduced into the standard porcelain mixture, this feldspar produces vitrification at 1,300° C. At 1,330° C. it showed no warpage, has a total shrinkage of 14.7 per cent, and a cream-white translucency of 72. The color is not altered under either the raw lead or fritted glaze.

RIDGEWAY. RIDGEWAY MICA COMPANY MINES.

This property (120) is one-fourth of a mile northwest of the depot at Ridgeway. The dike which is worked for mica is 5 to 10 feet wide and strikes nearly north. The feldspar is not present in sufficient quantities to make it any considerable asset to the company. It is chiefly a cream microcline. The associated mica is rum-colored muscovite and is very solid.

One-half mile northeast of the mica mine and between the highway and the railroad a dike similar to the one worked for mica has been exposed in a shallow pit. It carries more feldspar but the surface exposures available are badly stained with surface material, preventing a satisfactory sampling. The feldspar shows on both sides of the pit, which is about 8 feet across.

A number of pegmatite dikes more or less weathered are exposed along the line of the railroad in cuts north and south of Ridgeway Station. In most cases weathering is not sufficiently advanced to justify working the deposits for kaolin. The exposures are from 10 to 30 feet wide. Judging from the deeper workings in the mica mines, weathering may not continue to any great depth, and marketable feldspar might be obtained by removing this weathered material.

Much prospecting by shafts and cuts has been done throughout this district and little additional work should prove the quality and quantity of the deposits.

LIST OF FELDSPAR GRINDING MILLS.

The following list is based upon the fullest information obtainable but is not guaranteed to be complete.

FELDSPAR MILLS IN MAINE.

Maine Feldspar Co., Littlefield Station, Androscoggin County.
Maine Feldspar Co., Topsham, Sagadahoc County.
Trenton Flint & Spar Co., Cathance, Sagadahoc County.
These companies grind pegmatite from local quarries for use in making pottery.

FELDSPAR MILLS IN CONNECTICUT.

L. W. Howe, South Glastonbury, Hartford County.
The Wiarda Co., South Glastonbury, Hartford County.
These companies grind pegmatite from local quarries for use in making pottery, glass, and enamel.
The White Rocks Co., Middletown, Middlesex County.
This company crushes pegmatite from local quarries for roofing gravel, poultry grit, and concrete, but makes no pottery material.

FELDSPAR MILLS IN NEW YORK.

Crown Point Feldspar Co., Crown Point, Essex County.
Barrett Mfg. Co., Ticonderoga, Essex County.
These companies crush pegmatite from local quarries for use as roofing material, poultry grit, and stucco facing, but produce no pottery material.
Bedford Feldspar Co., Bedford Village, Westchester County.
P. H. Kinkel Sons, Bedford Village, Westchester County.
These companies grind pegmatite from local quarries for use in making pottery, glass, and enamel.
Pennsylvania Feldspar Co., Barnards, Monroe County.
This company grinds Canadian feldspar, chiefly for pottery purposes. The mill was destroyed by fire in December, 1914, but is being rebuilt.

MILLS IN NEW JERSEY.

Golding Sons Co., Trenton.
Eureka Flint and Spar Co., Trenton.
Both of these companies grind pegmatite from various districts in the United States.

MILLS IN DELAWARE.

Golding Sons Co., Wilmington.
This company grinds pegmatite from various producing districts in the United States.

MILLS IN PENNSYLVANIA.

Brandywine Summit Kaolin and Feldspar Co., Brandywine-Summit, Chester County.
This company grinds soda and potash pegmatite from local quarries.
Pennsylvania Feldspar Co., Toughkenamon, Chester County.
This company grinds Canadian feldspar and Pennsylvania pegmatite.
Meredith Mining & Milling Co., Pomeroy, Chester County.
This company crushes local pegmatite for poultry grit.

MILLS IN OHIO.

Golding Sons Co., East Liverpool.
Potter's Mining & Milling Co., East Liverpool.
This company grinds pegmatite from various districts in the United States.

MILLS IN WEST VIRGINIA.

The Newell Mining & Milling Co., Newell.
This company grinds pegmatite from various districts in the United States.

MILLS IN TENNESSEE.

The Clinchfield Mining & Milling Co., Johnson City.
This company grinds pegmatite from Mitchel and Yancey Counties, N. C.

PUBLICATIONS ON MINERAL TECHNOLOGY.

A limited supply of the following publications of the Bureau of Mines is temporarily available for free distribution. Requests for all publications can not be granted, and to insure equitable distribution applicants are requested to limit their selection to publications that may be of especial interest to them. Requests for publications should be addressed to the Director, Bureau of Mines.

BULLETIN 3. The coke industry of the United States as related to the foundry, by Richard Moldenke. 1910. 32 pp.

BULLETIN 16. The uses of peat for fuel and other purposes, by C. A. Davis. 1911. 214 pp., 1 pl., 1 fig.

BULLETIN 42. The sampling and examination of mine gases and natural gas, by G. A. Burrell and F. M. Seibert. 1913. 116 pp., 2 pls., 23 figs.

BULLETIN 45. Sand available for filling mine workings in the Northern Anthracite Coal Basin of Pennsylvania, by N. H. Darton. 1913. 33 pp., 8 pls., 5 figs.

BULLETIN 47. Notes on mineral wastes, by C. L. Parsons. 1912. 44 pp.

BULLETIN 53. Mining and treatment of feldspar and kaolin in the southern Appalachian region, by A. S. Watts. 1913. 170 pp., 16 pls., 12 figs.

BULLETIN 64. The titaniferous iron ores of the United States, their composition and economic value, by J. T. Singewald, jr. 1913. 145 pp., 16 pls., 3 figs.

BULLETIN 71. Fuller's earth, by C. L. Parsons. 1913. 38 pp.

BULLETIN 81. The smelting of copper ores in the electric furnace, by D. A. Lyon and R. M. Keeney. 1915. 80 pp., 6 figs.

BULLETIN 84. Metallurgical smoke, by C. H. Fulton. 1915. 94 pp., 6 pls., 15 figs.

BULLETIN 85. Analyses of mine and car samples of coal collected in the fiscal years 1911 to 1913, by A. C. Fieldner, H. I. Smith, A. H. Fay, and Samuel Sanford. 1914. 444 pp., 2 figs.

TECHNICAL PAPER 3. Specifications for the purchase of fuel oil for the Government, with directions for sampling oil and natural gas, by I. C. Allen. 1911. 13 pp.

TECHNICAL PAPER 8. Methods of analyzing coal and coke, by F. M. Stanton and A. C. Fieldner. 1913. 42 pp., 12 figs.

TECHNICAL PAPER 14. Apparatus for gas-analysis laboratories at coal mines, by G. A. Burrell and F. M. Seibert. 1913. 24 pp., 7 figs.

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TECHNICAL PAPER 39. The inflammable gases in mine air, by G. A. Burrell and F. M. Seibert. 24 pp., 2 figs.

TECHNICAL PAPER 41. Mining and treatment of lead and zinc ores in the Joplin district, Missouri, a preliminary report, by C. A. Wright. 1913. 43 pp., 5 figs.

TECHNICAL PAPER 43. The influence of inert gases on inflammable gaseous mixtures, by J. K. Clement. 1913. 24 pp., 1 pl., 8 figs.

TECHNICAL PAPER 50. Metallurgical coke, by A. W. Belden. 1913. 48 pp., 1 pl., 23 figs.

Technical Paper 66. Mud-laden fluid applied to well drilling, by J. A. Pollard and A. G. Heggem. 1914. 21 pp., 12 figs.

Technical Paper 68. Drilling wells in Oklahoma by the mud-laden fluid method, by A. G. Heggem and J. A. Pollard. 1914. 27 pp., 5 figs.

Technical Paper 70. Methods of oil recovery in California, by Ralph Arnold and V. R. Garfias. 1914. 57 pp., 7 figs.

Technical Paper 76. Notes on the sampling and analysis of coal, by A. C. Fieldner. 1914. 59 pp., 6 figs.

Technical Paper 81. The vapor pressure of arsenic trioxide, by H. V. Welch and L. H. Duschak. 1915. 21 pp., 3 pls., 2 figs.

Technical Paper 88. The radium-uranium ratio in carnotites, by S. C. Lind and C. F. Whittemore. 1915. 29 pp., 1 pl., 4 figs.

Technical Paper 95. Mining and milling of lead and zinc ores in the Wisconsin district, Wisconsin, by C. A. Wright. 1915. 39 pp., 2 pls., 5 figs.

Technical Paper 110. Monazite, thorium, and mesothorium, by K. L. Kithil. 1915. 32 pp., 1 fig.

INDEX.

A. Page.

Aerial tramways. *See* Tramways.
Alberton, Md., feldspar deposit near......... 164
 feldspar from, tests of............... 164
Albite, characteristics of..................... 30
 composition of.................... 30, 31, 96, 157
 specific gravity of....................... 30
 views of................................. 24
 See also Soda feldspar.
Albite pegmatite, composition of............ 16, 18, 20, 96, 97, 143, 146, 150, 163
Alkali in feldspar, amount of................ 33
Amelia Court House, Va., feldspar deposit near....................... 20, 167, 168, 169
 feldspar from, tests of.............. 168, 169
 view of.......................... 24
Andesine, composition of................. 31, 96, 140
 view of................................. 24
Andradite. *See* Garnet.
Anorthite. *See* Lime feldspar.
Anorthoclase, composition of, limits of...... 31
 definition of.......................... 30
Arendal, Norway, graphic granites in, composition of........................ 59
Arrington, Va., feldspar deposit near........ 166
Auburn, Me., feldspar deposits near... 112, 117-122
 feldspar from, composition of........ 96, 118, 119, 121
 tests of........................ 118-122
 view of.......................... 24
Avondale, Pa., feldspar deposits near...... 155, 156
 feldspar from, tests of............. 155, 156

B.

Back, Robert, analyses of feldspar by....... 95-97
Baker, Pa., feldspar deposit at.............. 155
 feldspar from, tests of............... 155
Ball mill, construction of.................... 84
 figure showing.......................... 85
 operation of............................ 85
Barium in feldspar, occurrence of............ 32
Barium feldspar, characteristics of.......... 30
 composition of........................ 30, 31
 specific gravity of...................... 30
Barium-potash feldspar. *See* Hyalophane.
Bastin, E. S., cited......................... 18, 58
 composition of feldspar by.........120, 121, 127
 on composition of graphic granites....... 54
Batchellerville, N. Y., feldspar deposit near. 136-138
 feldspar from, composition of... 96, 137, 138
 tests of.........................136-138
 view of.......................... 24
Batchellerville district, N. Y., extent of..... 14
 feldspar from, analyses of............... 15
 character of......................... 14
Bath, Me., feldspar deposit near,............ 108

Page.

Bedford, N. Y., feldspar deposits near..... 141-144
 feldspar from, composition of... 96, 141-143
 tests of......................... 141-144
 view of.......................... 24
 graphic granite from, composition of.... 54, 55, 59, 96
Beryl, composition of........................ 27, 43
 in feldspar, effect of.................... 42, 43
 removal of........................ 27
 in pegmatites, occurrence of............. 27
Biotite, composition of...................... 44
 in feldspar, effect of.................... 44, 46
 need of removing..................... 19
 in pegmatites, occurrence of............. 26
Black mica. *See* Biotite.
Blandford, Mass., feldspar deposit near...... 12
Bolting of feldspar........................... 87
Boothbay district, Me., extent of............ 9
 feldspar in............................... 9
Boothwyn, Pa., feldspar deposit near 147, 148
 feldspar from, tests of............... 148
Buhrstone chaser, description of............ 81, 82
 figure showing............................ 82
 operation of.............................. 82
Bureau of Mines, investigation of............ 3, 4
Bygden, A., on composition of graphic granite. 54
Bytownite, composition of, limits of......... 31

C.

Cathance, Me., feldspar deposits near...... 102-106
 feldspar from, composition of... 96, 105, 106
 tests of................... 103, 104, 106
 graphic granite from, composition of..... 54, 55, 59, 106
 view of.......................... 10
Celsian. *See* Barium feldspar.
Chatham, Pa., feldspar deposit near......... 153
 feldspar from, tests of................ 153
Chelsea, Pa., feldspar deposit near........... 147
Chester Heights, Pa., feldspar deposit near. 146, 147
 feldspar from, tests of.............. 146, 147
 pegmatite from, composition of......... 96, 146
Cleavelandite, characteristics of.............. 30
 See also Soda feldspar.
"Cobbing" feldspar, mode of............... 6, 7
Conical mills, construction of................ 87
 operation of.............................. 87
Connecticut, feldspar deposits in..... 12, 13, 123-132
 feldspar from, composition of....13, 126-129
 tests of.................. 90, 93, 124-130
 results of, curves showing.... 92
 map showing......................... 122
 See also localities named.
Conowingo, Md., feldspar deposit near....... 159
 feldspar from, tests of................ 159

Page.
Corinth, N. Y., feldspar deposits near........ 135
feldspar from, tests of................ 135
Cornish pump. *See* Pump.
"Cornwall stone," importation of............ 6
Cowee district, N. C., feldspars in, character of 21
mining of........................... 22
Cramer, E., standard cones made by......... 64
Cranberry, N. Y., feldspar deposit near...... 140
feldspar from, composition of....... 96,140
tests of........................ 140,141
Crown Point, N. Y., feldspar deposit near... 132,133
feldspar from, composition of....... 96,133
tests of.......................... 133
view of.......................... 24
Crusher, buhrstone faces for, advantage of... 82,83
gyratory, classes of...................... 81
objection to......................... 81
jaw, classes of............................ 80
figure showing....................... 81
See also Buhrstone chaser.

D.

Darlington, Pa., feldspar deposit near....... 145
feldspar from, composition of....... 96,145
tests of........................ 145,146
Davis, Md., feldspar deposit near............ 160
feldspar from, tests of................ 160
Deformation of feldspar cones, definition of.. 64
factors in............................... 66
stages in................................ 66
Deformation point of feldspar, determination of.. 67,68
Demorest, D. J., analyses of feldspar by..... 95-97
Dike, definition of........................... 7
pegmatitite, character of................. 7
origin of.............................. 7,8
structure of.......................... 8
sampling of.............................. 61,62
Dike material, handling of.................... 75
quarrying of, classification of............ 73-74
explosives used in.................. 74
precautions in...................... 71,72
sorting of................................ 75
Dixfield, Me., feldspar deposit near.......... 113
feldspar from, tests of............... 113

E.

East Orland, Me., feldspar deposit at........ 9,100
feldspar from, tests of................ 100
pegmatite dike at, view of.............. 10
Edgecomb, Me., feldspar deposits at....... 101,102
feldspar from, tests of.............. 101,102
Elam, Pa., feldspar deposit at............... 148
feldspar from, tests of................ 149
Elfkarleo, —, graphic granites in, composition of.................................... 59
Elutriator. *See* Schultze elutriation apparatus.
Embreeville, Pa., feldspar deposit at....... 150,151
feldspar from near, tests of........... 151
Europe, grinding of feldspar in 84
Evje, —, graphic granites in, composition of. 59

F. Page.

Feldspar, classification of.................... 23,28
cleaning of, method of................... 6,7
color of.................................. 24
composition of, relation of, to deformation test.................................. 33
distribution of............................ 4
drying of, need of........................ 80
fused, effect of color in.................. 23,24
fusion of, temperature of................ 63
viscosity of......................... 63-65
grading of................................ 5
handling of, details of............ 6,79,88,94,95
kaolinization of, effects of................ 46
method for sampling...................... 61,62
methods of crushing...................... 80
methods of pulverizing................... 83,84
See also Grinding.
minerals associated with. *See* minerals named.
properties of, in porcelain mixtures, tests of.. 68-71
prospecting for........................... 60
method of........................... 60,61
pulverized, classification of, curves showing.................................... 91,92
deformation tests of, figure showing.. 94
results of....................... 93
size of grains of...................... 89-93
wetting of, objections to............. 87,88
quality of, relation of, to price........... 23
relative value of, factors determining.... 22
standard, composition of.................. 71
deformation temperature of.......... 71
uses of................................... 4,5
wastes in mining of....................... 5
prevention of......................... 4
See also Pegmatite, feldspars named; localities named.
Feldspar beryl cones, deformation of, figure showing............................ 43
preparation of......................... 43
tests of............................... 42,43
Feldspar-biotite cones, deformation of, figure showing............................ 45
preparation of............................ 44
Feldspar-muscovite cones, deformation of, figure showing...................... 44
tests of............................... 43,44
Feldspar quarries, list of..................... 98,99
Feldspar-quartz cones, deformation of, figure showing............................ 41
tests of............................... 41,42
See also Potash feldspar-quartz cones; Soda feldspar-quartz cones.
Fieldner, A. C., analysis of graphic granites by.. 54
Flint, effect of, on deformation of feldspar... 38
France, supply of feldspar in................ 6
Frit, composition of.......................... 71
Fritted glaze. *See* Glaze.

G.

Garnet, composition of....................... 26
in pegmatites............................ 26,27
removal of............................ 26,27

Page.
Georgetown Peninsula, Me., feldspar deposits at........ 102, 109, 110
feldspar from, tests of........ 102, 110
graphic granite from, composition of........ 54, 55, 59, 96, 110
view of........ 10
Georgia, feldspars in........ 22
Glaze, composition of........ 70
effect of, on porcelain mixtures........ 70
Granite, Md., feldspar deposits near........ 159, 160
feldspar from, tests of........ 160
Granite, graphic, composition of........ 53–55, 96, 106, 110, 119, 127, 151, 152
deformation of, figure showing........ 56
tests of........ 55–57
feldspar in........ 51, 52
relation of, to fusibility........ 56
quartz content of, determination of........ 57, 58
value of........ 53
view of........ 10
See also Pegmatite.
Graphic granites. *See* Granite.
Grinding of feldspar, mills for, list of........ 172, 173
types of........ 84
See also Ball mills; Conical mills; Tube mills.
wet, apparatus for........ 84
objection to........ 84

H.

Haddam, Conn., feldspar deposit near........ 131
feldspar from, tests of........ 131
Haulage from quarry, factors affecting........ 78
Haulage systems in quarries........ 78, 79
Heat-radiation pyrometers. *See* Pyrometers.
Hebron, Me., feldspar deposits at........ 115, 116
feldspar from, composition of........ 96, 116
tests of........ 115, 116
Hewletts, Va., feldspar deposit near........ 20, 169
feldspar from, tests of........ 169
view of........ 24
Hitteren, Norway, graphic granites in, composition of........ 59
Hyalophane, composition of........ 31
definition of........ 31
occurrence of........ 32
Hyalophane series of feldspars, classification of........ 29

I.

Iddings, J. P., on classification of feldspars........ 28
Ilchester, Md., feldspar deposit near........ 161
feldspar from, tests of........ 161
Iron, elimination of, from powdered rock........ 81
Iron oxide, injury to feldspar from........ 73

J.

Jetersville, Va., feldspar deposits........ 20, 167
feldspar from, tests of........ 167
Johnson, H. E., on composition of graphic granites........ 53

K. Page.

Kaolin, composition of........ 47
Kaolin-feldspar cones, deformation tests of, data on........ 50
figure showing........ 48, 49, 50, 52
results of........ 48, 49
preparation of........ 47
refiring of, results of........ 49
Kaolin-feldspar-quartz cones, deformation of, figure showing........ 50
results of........ 50

L.

Labradorite, composition of........ 31
Lime feldspar, characteristics of........ 30
composition of........ 30, 31
proportion of, in graphic granites........ 59
specific gravity of........ 30
Lime in feldspar........ 32
Lime-soda feldspar. *See* Plagioclase.
Locomotives for haulage, electric........ 78
steam........ 78
Lowry, Va., feldspar deposit near........ 165
feldspar from, composition of........ 97, 165
tests of........ 165

M.

Magnesium-aluminum silicate, composition of........ 97, 157
Magnetite, composition of........ 28
in pegmatites........ 28
removal of........ 28
Maine, feldspars from, analyses of........ 11
classification of, curves showing........ 91
precautions in treatment of........ 22
tests of........ 89, 90
feldspar districts in........ 9–11
map showing........ 100
graphic granites of, tests of........ 55–57
See also localities named.
Marriottsville, Md., feldspar deposits near........ 161–163
feldspar from, tests of........ 162
pegmatite from, composition of........ 97, 162
Maryland, feldspar in........ 19, 159–164
analyses of........ 20
deposits of, map showing........ 146
extent of........ 19, 20
See also localities named.
Massachusetts, feldspar in........ 12, 122, 123
deposits of, map showing........ 122
Mendenhall, Pa., feldspar deposits near........ 149
feldspar from, composition of........ 96, 150
tests of........ 149, 150
Mica, separation of........ 83
Microcline, composition of........ 15–17, 29, 31, 47, 96, 133, 142, 145, 146, 150
description of........ 29
occurrence of........ 29
specific gravity of........ 29, 47
views of........ 24
See also Orthoclase; Potash feldspars.
Microcline pegmatite, composition of........ 16, 20, 96, 97, 163
Middle Haddam, Conn., feldspar deposits near........ 130, 131
feldspar from, tests of........ 130, 131

Page.
Middletown, Conn., feldspar deposits near. 128-130
feldspar from, composition of....... 96,129
tests of....................... 129,130
Mount Apatite, Me., feldspar deposits near. 118,119
feldspar from, composition of....... 96,118
tests of....................... 118,119
Mount Apatite district, Me., extent of....... 10
feldspar in............................ 10
Mount Mica district, Me., extent of.......... 10
feldspar deposits in.................. 10,11
Muscovite, composition of.................. 43,44
in feldspar, effect of..................... 43,44
removal of............................ 26
in pegmatites............................ 25,26

N.

New Castle, Me., feldspar deposits near...... 100
feldspar from, composition of........ 96,101
tests of............................ 101
New Garden, Pa., feldspar deposits near.. 151,156
feldspar from, tests of.............. 152,156
graphic granite from, composition of. 96,151
New Hampshire, feldspar deposits in........ 12
New York, feldspar deposits in...... 13-16,132-145
map showing......................... 132
See also localities named.
North Carolina, feldspar deposits in.......... 21
feldspar in, analyses of.................. 22
North Castle, N. Y., feldspar deposit near.. 144,145
feldspar from, tests of................ 145
North Groton, N. H., mica quarry near..... 12
Northville, N. Y., feldspar deposits near... 138,139
feldspar from, tests of.............. 139,140
view of.......................... 24
Norway, Me., feldspar deposits near........ 116,117
feldspar from, composition of....... 96,117
tests of............................ 117

O.

Oligoclase, composition of................... 31
Ontario, Canada, feldspar from, view of..... 24
Optical pyrometers. *See* Pyrometers.
Orthoclase, characteristics of................ 29
composition of............................ 46
specific gravity of........................ 29
See also Potash feldspars.
Overburden, removal of..................... 73,74
Owls Head, Me., feldspar deposit near....... 114
Oxford, Conn., feldspar deposit near......... 132

P.

Paris Hill, Me., feldspar deposit at.......... 116
feldspar from, tests of................ 116
Parsons, C. L., work of...................... 95
Pegmatite, composition of......... 25-28,96,97,160
See also Feldspar; Granite, graphic.
Pegmatite dike, weathered, view of.......... 10
Penland, N. C., microcline from, view of..... 24
Pennsylvania, feldspars in........... 16-18,145-158
classes of............................ 17
composition of...... 17,145,146,150-152,157
minerals associated with............ 18,19
feldspar district of........................ 16
map showing......................... 146
See also localities named.

Page.
Phippsburg, Me., feldspar deposit at....... 110,111
feldspar from, composition of....... 96,111
tests of.......................... 111
view of.......................... 24
Plagioclase, analysis of...................... 15
classification of...................... 28,29,30
definition of............................. 31
Plumtree, N. C., microcline from near, view of.................................. 24
Pomeroy, Pa., feldspar deposit near.......... 152
feldspar from, tests of.............. 152,153
graphic granite from, analysis of......... 96
Porcelain mixtures, composition of.......... 68
firing of.................................. 69
preparation for tests..................... 68,69
shrinkage of, determination of........... 69
tests of.................................. 70,71
translucency of, determination of........ 69
value of feldspar in...................... 68
Portland, Conn., feldspar deposit near 127,128
feldspar from, composition of....... 96,128
tests of.......................... 128
view of.............................. 24
graphic granite from, composition of.. 54,55,59
Potash feldspar, composition of.............. 11, 13,18,22,32-34,36,40,96,105
definition of............................. 31
deformation range of...................... 11,13
occurrence of............................. 7,29
proportion in graphic granites............ 59,60
See also Microcline; Orthoclase.
Potash feldspar-quartz cones, deformation tests of.......................... 36,37,40
results of, figure showing............ 37
preparation for test...................... 40
Potash feldspar-soda feldspar cones, composition of............................ 34
deformation tests of...................... 33-36
figure showing........................ 35
Potash in feldspar........................... 32
Prospect, Va., feldspar deposit near....... 166,167
feldspar from, tests of................ 167
Prospecting for feldspar...................... 60
Pulverization of feldspar. *See* Feldspar.
Pumps for quarries, troubles with........... 77
types of.................................. 77
Pyrometers, description of.................. 67
types of.................................. 66
use of.................................... 67
Pyrometric cones, fusion temperature of..... 64
manufacture of....................... 64,65
testing of............................ 65,66

Q.

Quarries, haulage methods in................ 78,79
opening of, precautions in................ 72,73
removing water from..................... 76,77
Quarrying below water level, expense of..... 75,72
method of................................ 75,76
Quartz, composition of...................... 36,38
in feldspars, effect of............... 36,38,39,42
in graphic granite.......................... 25
determination of..................... 57,58
occurrence of......................... 25
proportion of......................... 59,60

R. Page.

Raw-lead glaze. *See* Glaze.
Reade—graphic granites in, composition of.. 59
Ridgeway, Va., feldspar deposits near..... 169,170
feldspar from, tests of.............. 170,171
Rieke, R., on deformation of muscovite...... 43
Riggsville, Me., feldspar deposit near........ 109
Rock crushers. *See* Crushers.
Rock Springs, Md., feldspar deposit near.... 159
Rocky Hill, Conn., feldspar deposit near... 126,127
feldspar from, composition of...... 126,127
tests of.......................... 127
Rodo, —, graphic granites in, composition of. 59
Roseland, Va., feldspar deposit near....... 21,166
Rosenbusch, K. H. F., classification of feldspars by.......................... 29

S.

St. Yrieix district, France, treatment of feldspars from.......................... 6
Sampling of feldspar, method for............ 61,62
Schultze elutriation apparatus, description of. 89,90
figure showing........................... 89
operation of............................. 90
Seger, Herman, standard cones made by..... 64
Seger cones. *See* Pyrometric cones.
Sieves for separating feldspar, types of....... 83
Silica, effect of, on feldspar.................. 36
Sills, definition of............................ 7
pegmatite, character of................. 7
See also Dikes.
Simonis, —, on deformation of kaolin-feldspar mixtures.................. 46,51
Skarpo, —, graphic granites in, composition of................................... 59
Soda feldspar, composition of... 11,96,32–34,38,118
deformation range of.................... 11
occurrence of............................ 7
proportion of, in graphic granites........ 59,60
See also Albite; Cleavelandite.
Soda feldspar-quartz cones, deformation of, figure showing..................... 39
tests of.............................. 38
results of........................ 39
preparation for test..................... 38
Soda in feldspar, effect of.................... 32,36
Soda-microcline. *See* Anorthoclase.
South Freeport, Me., feldspar deposit at... 111,112
feldspar from, tests of............... 112
South Glastonbury, Conn., feldspar deposits near............................ 123–126
feldspar from, composition of....... 96,126
tests of........................ 124–126
South Paris, Me., feldspar deposit near...... 113
tests of............................ 113,114
Sprucepine district, N. C., feldspars in...... 21
mining of........................... 22
Staffordshire, England, potteries, feldspars used in.............................. 5,6
Steam pump. *See* Pumps.

Page.

Steiger, George, analysis of graphic granites by................................. 54
Sylmar, Md., feldspar deposits near....... 156–158
feldspar from, composition of....... 96,157
tests of.......................... 157
view of.............................. 24

T.

Teall, J. J. H., on composition of graphic granites............................ 53
Thermoelectric pyrometers. *See* Pyrometers.
Ticonderoga, N. Y., feldspar deposits near. 133–135
feldspar from, composition of....... 96,134
tests of.......................... 134
view of.............................. 24
Ticonderoga district, N. Y., feldspar in...... 13,14
mining of........................... 14
Topsham, Me., feldspar deposits near,..... 107–109
feldspar from, tests of.............. 107,108
graphic granite from, composition of.. 54,55,59
view of.............................. 10
Toughkenamon, Pa., feldspar deposits near, 153,154
feldspar from, tests of.............. 153,154
Tourmaline, composition of.................. 27
in pegmatites............................ 10,27
Tramways, aerial, systems of................ 79
Tube mill, construction of.................... 86
figure showing............................ 86
operation of............................. 86

U.

United States Geological Survey, samples collected by........................... 54

V.

Virginia, feldspar deposits in................. 20,21
feldspar from..................... 20,21,165–171
composition of....................... 21,165
Vitrification range of feldspar, definition of.. 69
determination of.......................... 69
Vogt, J. H. L., on composition of graphic granites............................ 53

W.

Water in quarries, removal of................ 76,77
Watts, A. S., on kaolization of feldspar....... 46,47
samples collected by...................... 54
Westchester County district, N. Y., feldspar in.................................. 15
analyses of.......................... 16
Wilson, Hewitt, on effect of kaolin on feldspar................................ 46–51
Woodstock, Md., feldspar deposits near...... 163
feldspar from, tests of.............. 163,164
pegmatite from, composition of......... 97,163

Y.

Ytterby, —, graphic granites in, composition of.................................. 59