GJBX-258 '80

National Uranium Resource Evaluation

CORDILLERAN METAMORPHIC CORE COMPLEXES AND THEIR URANIUM FAVORABILITY

APPENDICES

Peter J. Coney and Stephen J. Reynolds

with contributions by
George H. Davis, Stanley B. Keith, Paula F. Trever, Steven H. Lingrey,
Charles F. Kluth, Diane C. Ferris, James F. DuBois and James J. Hardy

LABORATORY OF GEOTECTONICS
DEPARTMENT OF GEOSCIENCES, UNIVERSITY OF ARIZONA
Tucson, Arizona 85721

with the cooperation of
ARIZONA BUREAU OF GEOLOGY AND MINERAL TECHNOLOGY
Tucson, Arizona 85721

November 1980

PREPARED FOR U.S. DEPARTMENT OF ENERGY
Assistant Secretary for Resource Applications
Grand Junction Office, Colorado

This report is a result of work performed by the Laboratory of Geotectonics, Department of Geosciences, University of Arizona, through a Bendix Field Engineering Corporation Subcontract, as part of the National Uranium Resource Evaluation. NURE is a program of the U.S. Department of Energy's Grand Junction, Colorado, Office to acquire and compile geologic and other information with which to assess the magnitude and distribution of uranium resources and to determine areas favorable for the occurrence of uranium in the United States.

Bendix

Field Engineering Corporation

Grand Junction Operations

P. O. Box 1569
Grand Junction, CO 81502
Tel (303) 242-8621

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January 7, 1981

To: All Holders of GJBX-258(80), " Cordilleran Metamorphic Core Complexes and their Uranium Favorability"

Subject: Errata

Please replace page 291 of the noted report with the enclosed, corrected page.

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Corporation

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Grand Junction, CO 81502
Tel (303) 242-8621

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To: All holders of GJQ-005(80), "National Uranium Resource Evaluation, Raton Quadrangle, New Mexico and Colorado"

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Please make the following corrections to the noted document:

1. Page 33, Plate 7. Trim the enclosed crack and peel correction to approximately 1 inch by 2 inches and place at the bottom of the legend column, directly under the Paleozoic designation.
2. Page 47, Plate 14. Trim the zero (0) correction to approximately ¼ inch by 1 inch and place over the sea level designation in the lower right hand section of the plate.

TABLE 5-5:
AVERAGE CHEMICAL COMPOSITION OF COMPONENTS WITHIN THE WILDERNESS GRANITE STACKED SILL COMPLEX

increasing structural level ———→

			MAIN RANGE SILL							
			Lower Portion		Upper Portion					
Element^{3} or Element Oxide^{4}	Seven Falls Foliated granite	n^{1}	Foliated biotite granite	n	Two-mica granite	n	Lemmon Rock leucogranite	n	Garnet schlieren	n
SiO_2	64.88	1	70.6	1	74.06	13	75.2	2	70.63	1
AL_2O_3	16.6	1	14.5	1	14.67	13	13.1	2	13.5	1
Fe_2O_3	.81	1	1.01^{2}	1	.50	10	.29	4	1.51	1
FeO	1.42	1	.68^{2}	1	.39	10	.195	4	1.39	1
MgO	.59	1	.32	1	.19	13	.06	2	.17	1
CaO	3.14	1	1.81	1	1.3	13	.44	5	.25	1
Na_2O	5.61	1	3.51	1	3.92	13	4.04	2	2.08	1
K_2O	2.09	1	4.23	1	3.62	13	4.48	5	1.92	1
P_2O_5	.14	1	.10	2	.041	13	.09	2	.03	1
U	.90	1	.90	2	1.37	14	3.5	2	28.5	1
Th	6	1	6.5	2	^{2}<4.8	14	^{2}<2.5	2	50	1
Sc	4	1	5	2	3.3	14	<5.0	2	9	1
Ti	2200	1	2050	2	7.70	15	110	4	280	1
Mn	350	1	345	2	4.70	15	19.80	5	34,000	1
Y	10	1	11.5	2	7.6	14	8.5	2	270	1
Ce	76	1	52	2	<37	14	< 25	2	53	1
Nb	<4	1	4	2	<8.5	14	<72	2	24	1
Ba	1100	1	2050	2	13.75	15	482	2	21	1
Li	27	1	14.5	2	26	14	128	2	32	1
V	35	1	21.5	2	7.	14	2	1	< 2	1
Cu	7	1	9	2	15.	15	19.5	2	4	1
Zn	72	1	81.5	2	65.	15	155.	5	260	1
Cr	6	1	6.5	2	7.	14	19.5	2	5	1
Ni	4	1	6	2	< 4.5	14	12	2	< 4	1
Be	2	1	1	2	2.1	14	7.5	2	2	1
Rb			70	1	121	12	378	7		
Sr	760	1	490	2	320	25	28.3	7	10	1

<u>Notes:</u>
1) n= number of samples
2) Less than sign (<) indicates some samples for the element in question were below the detection limit for that element.
3) Element analytical values are in ppm.
4) Element oxide values are in weight percent.

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November, 1980

PREPARED FOR THE U.S. DEPARTMENT OF ENERGY
ASSISTANT SECRETARY FOR RESOURCE APPLICATIONS
GRAND JUNCTION OFFICE, COLORADO
UNDER CONTRACT NO. DE-AC13-76GJ01664
AND BENDIX FIELD ENGINEERING CORPORATION
SUBCONTRACT NO. 79-357

APPENDICES*

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*Appendices and final report are bound in separate volumes.

APPENDIX A

ANNOTATED BIBLIOGRAPHY OF CORDILLERAN METAMORPHIC CORE COMPLEXES

By

Diane C. Ferris and Stephen J. Reynolds

Introduction

The bibliography lists all references pertinent to Cordilleran metamorphic core complexes. Literature and data sources included in the compilation are those which apply to the geologic aspects of the complexes. Each reference is annotated, the primary topics discussed in that reference being denoted by a character coding. Following is a list of the codes with an explanation of each:

A - Data and interpretation bearing directly on the description and understanding of metamorphic core complexes.

  A1 - Regional geologic setting
  A2 - Structure and stratigraphy of cover rocks
  A3 - Nature of dislocation zone
  A4 - Petrology, geochemistry and structure of lineated mylonitic rocks
  A5 - Petrology, geochemistry, and structure of plutonic and metamorphic rocks of the crystalline core
  A6 - Geochronology

B - Tectonic events bearing indirectly on the geologic evolution of metamorphic core complexes

  B1 - Basin and Range overprint
  B2 - Tertiary listric-normal faulting and accompanying tilting or rotation
  B3 - Tertiary magmatism
  B4 - Late Mesozoic - early Tertiary compressional tectonics
  B5 - Mesozoic magmatism, metamorphism, deformation, and sedimentation
  B6 - Pre-Mesozoic events
  B7 - Regional episodes of mineralization

C - Related topics

- C1 - Mylonitic - cataclastic deformation
- C2 - Gneiss domes
- C3 - Tectonic evolution of the North American Cordillera
- C4 - Petrology, geochemistry and mineral deposits

References denoted within 'A-class' coding are those dealing with the geology of the core complex or with the geology of areas immediately surrounding them. 'B-class' codings annote those references describing regional tectonic events. These papers may not deal directly with metamorphic core complex geology; they are, however, germane to an understanding of core complex phenomena in their regional settings. References annotated with 'C-class' codes furnish the reader with a general approach to the problems of petrology and processes within core complexes. An asterisk (*) has been placed to the left of those references that emphasize key issues and basic concepts of Cordilleran metamorphic core complexes.

The bibliography was compiled by Diane C. Ferris. Stephen J. Reynolds annotated the bibliography following suggestions from George H. Davis.

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APPENDIX B

ANNOTATED BIBLIOGRAPHY OF THE URANIUM FAVORABILITY OF CORDILLERAN METAMORPHIC CORE COMPLEXES

by

Stephen J. Reynolds

Introduction

This bibliography contains references pertinent to the uranium favorability of Cordilleran metamorphic core complexes. Important topics discussed in each reference are indicated by the following annotations.

A - Geology, geochemistry and mineralogy of uranium

  A1 - Regional variations in uranium abundance
  A2 - Geology of uranium deposits
  A3 - Geochemistry and mineralogy of uranium

B - Uranium and processes relevent to Cordilleran metamorphic core complexes

  B1 - Plutonic processes
  B2 - Metamorphic processes
  B3 - Mylonitic processes
  B4 - Processes related to dislocation surfaces
  B5 - Processes extrinsic to the evolution of Cordilleran metamorphic core complexes

C - Geology and uranium occurrences of Cordilleran metamorphic core complexes

  C1 - Washington - northern and central Idaho - Montana
  C2 - Southern Idaho - Nevada - Utah
  C3 - California - Arizona

References with 'A' class annotations discuss the general geology, geochemistry and mineralogy of uranium. The references included in this class are those most relevant to the evaluation of uranium favorability of Cordilleran metamorphic core complexes or which contain valuable bibliographies. The subdivision of 'B' class annotations parallels that in Chapter 4 in which separate sections are devoted to different types of processes. An extensive compilation of literature that describes the geology, geochemistry, petrology and tectonic setting of peraluminous, muscovite-bearing granitoids of the world is incorporated into the 'B1' annotation. Data from many 'B1' papers were used to construct figures in Chapters 4 and 5. References with 'C' class annotations discuss the geology and uranium occurrences of the northern (C1), central (C2), and southern (C3) thirds of the core complex belt. Only key papers on the geology of each complex are listed here since Appendix A is a complete Bibliography on the subject. This bibliography was compiled and annotated by Stephen J. Reynolds with assistance from Diane C. Ferris and Jeanne Woodward.

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APPENDIX C

URANIUM OCCURRENCES IN THE CORDILLERAN METAMORPHIC CORE COMPLEX BELT

By

Diane C. Ferris

Introduction

The appendix consists of a list of all known uranium occurrences within the Cordilleran metamorphic core complex belt and is meant to accompany maps C-1 through C-7 of this report. Within the appendix is found the designating number, county, location, and reference for the data points displayed on the maps.

The uranium occurrences detailed on the maps are symbolized by a scheme which strictly employs a host rock classification. No genetic inferences have been drawn above or beyond the practice of differentiating between deposits that are disseminated in the host rock, or, alternatively, controlled by some obvious secondary or lithologic feature.

Four basic host rock types were chosen (sedimentary, volcanic, plutonic, and metamorphic) and a modifying scheme was devised to further define the occurrence type and age, where information permitted.

Following is a brief description of the criteria by which host rock types were defined and classified, together with an explanation of the remaining symbology shown on the legends of maps C-1 through C-7.

Host Rock Types

Sedimentary

A sedimentary host rock symbol (the circle) has been applied to those deposits occurring in all classic lithic sedimentary environments as well as to those occurring in unconsolidated sediments such as lake beds, placers, river gravels, and muds. In addition, because the metamorphic/plutonic environment has received the strictest definition, some metamorphosed rocks possessing obvious sedimentary protoliths -- that are in effect metasediments -- have been included in the 'sedimentary' category. This principle applies most noticeably to the quartzites and metasediments of the Belt Supergroup of the northwestern U.S. This distinction has been made so that the crystalline-metamorphic character of the core of each complex can be readily separated from the rocks of the cover.

Volcanic

A volcanic host rock has been symbolized by the triangle. Any extrusive rock type has been classified as 'volcanic'. The category, in a very few cases in western Arizona and in California, has been expanded to include extremely shallow hypabyssal intrusives that were known to be intimately associated with extrusive rock. Where no other information was available and the source reference listed only "tuffs" (or "bedded tuffs") as the host rock, the occurrence was classified as volcanic in type.

Plutonic

A plutonic host rock symbol has been applied to all deposits occurring in intrusive igneous environments, thus the category encompasses all common intrusives plus "intrusives" such as "pegmatites", "aplites" and "dikes". In many cases the literature provided no clue as to the host rock for an anomalous intrusive feature. In these cases the host rock was tentatively assigned a plutonic designation (symbol bears a question mark). All occurrences referenced as "crystalline" were also classified as plutonic. The plutonic environment is shown on the map by a square.

Metamorphic

The metamorphic designation has been narrowly defined and applied in the classification scheme employed. Host rocks have been classified as metamorphic (the hexagon) if they consist of schist, gneiss, gneissic granite or migmatite. Marble and quartzite have been included in the metamorphic category only if they are associated with the above lithologic types. In addition, rock types that exhibit foliation or that exhibit a variably developed mylonitic fabric have been classified as metamorphic.

Unknown

In some cases the source literature used in the compilation did not identify the lithology of the rock in which the anomalous occurrence was found. A shield shaped symbol has been used to denote an unknown host rock lithology.

Symbols

Age Designation

Where the host rock is Tertiary or younger, or where the deposition of uranium is demonstrably Tertiary or younger the map symbol has been modified. A Tertiary-Quarternary age has been denoted by darkening the lower half of the host rock symbol. Age date information is extremely scarce in uranium occurrence literature, therefore, most symbols have remained unmodified.

Structural/Lithologic Control

Host rock symbols for uranium occurrences exhibiting structural/lithologic control have been modified. A diagonal line cutting the host rock symbol denotes a variety of controls including:
a) structural -- faults, joints, fractures, breccias, pipes;
b) intrusive -- dikes, veins, veinlits, hydrothermal alteration zones;
c) lithologic -- bedding, sedimentary structures, mylonite zones, foliation. The host rock symbol has remained unmodified if the literature does not indicate specific controls or if the deposit has been classified as disseminated.

Additional Points

1. Where there are question marks in the symbol, the host rock type has been inferred from the available information. In these cases, host rock type was not explicitly stated but a reasonable assumption could be made.

2. Two over-lapping symbols are sometimes displayed for one occurrence. This indicates one of two possibilities: first, that the radioactive occurrence was found in both rock types or that a structural feature between the two rocks was anomalous; second, that the reference listed both rock types and did not specify the host rock. In either case, the map displays two symbols for both host rock types.

3. Gaps in the sequential annotation of the uranium occurrences in the following appendix are a function of the compilation method. Missing numbers are not a result of an error in compilation or of missing data points.

4. The area encompassed by the uranium compilation consists of a relatively continuous swath extending the entire length of the metamorphic core complex belt. The width of the compilation area has been extended to approximately 50-75 miles on either side of each complex. All uranium occurrences have been shown on maps C-1 through C-7 for those counties that fall either partially or totally within the 50-75 mile range. County lines appear only for those counties for which uranium compilations have been made.

5. In Appendix C, the source reference for each occurrence has been denoted by an abbreviation in the right-hand column. Following is a list of those abbreviations accompanied by their complete reference:

Source Abbreviation	Reference
B	Bendix Field Engineering Corporation, 1980, Preliminary maps and tables of uranium occurrences: Bendix Field Engineering Corporation, Grand Junction, Colorado (unpublished).
G	Garside, L. J., 1973, Radioactive mineral occurrences in Nevada: Nevada Bureau Mines and Geology Bull. 81, 121 p.
GJBX 36/78	Larson, L. T., Beal, L. H., Firby, J.R., Hibbard, M. J., Slemmons, D.B., and Larson, E. P., 1978, Great Basin geologic framework and uranium Faborability: U.S. Department of Energy GJBX-36(78), Open File Report, 178 p.
M	Minobras, 1977, Uranium deposits of the northern U.S. region: Minobras, Dana Point, California, 99 p.
PRR	Preliminary Reconnaissance Reports for the Western United States: U.S. Atomic Energy Commission, Grand Junction, Colorado.
S&K	Scarborough, R. B., and Kresan, P., Radioactive occurrences of Arizona: U.S. Department of Energy GJBX, Open File Report (in preparation).

ARIZONA (Map C-1)

COCHISE COUNTY

		Location		
Map No.	Section	Township	Range	Data Source
A-300	16	23S	24E	S&K
A-301	25	18S	19E	S&K
A-302	9-16	23S	20E	S&K
A-303	17	24S	29E	S&K
A-304	1	18S	25E	S&K
A-305		18S	19E	S&K
A-306	35	17S	25E	S&K
A-307	9	18S	19E	S&K
A-308	33,34	17S	25E	S&K
A-309	8	14S	21E	S&K
A-310	4	24S	29E	S&K
A-311	10	18S	19E	S&K
A-312	22,23	20S	27E	S&K
A-313	9	24S	29E	S&K
A-314	9,10?	18S	19E	S&K
A-315		18S	19E	S&K
A-316	30	13S	19E	S&K
A-317	2	18S	20E	S&K
A-318	35	15S	22E	S&K
A-319	31	14S	28E	S&K
A-320	25,26	18S	19E	S&K
A-321	25,36	13S	28E	S&K
A-322	32	14S	28E	S&K
A-323	32	14S	28E	S&K
A-324	7	14S	27E	S&K
A-325	22	13S	26E	S&K
A-326	17	23S	20E	S&K
A-327	10	18S	19E	S&K
A-328	30	13S	19E	S&K

GILA COUNTY

		Location		
Map No.	Section	Township	Range	Data Source
A-603	20	3N	17E	S&K
A-605	35,2?	2N&3N	14E	S&K
A-606	9	1S	14E	S&K
A-607	6	1S	14E	S&K
A-608	14	2N	14E	S&K
A-609	21,22?	1N	14E	S&K
A-610	29,30?	4S	16E	S&K
A-611	6	1N	15E	S&K
A-612	36	3N	16E	S&K
A-613	22,23			
	27,26	12N	2E	S&K
A-614	5,8	6N	11E	S&K

GILA COUNTY (cont)

Map No.	Location Section	 Township	 Range	Data Source
A-615	22,21	4N	14E	S&K
A-617	18	4N	17E	S&K
A-618	21?	2N	16E	S&K
A-619	5	8N	11E	S&K
A-620	12	1S	14½E	S&K
A-621	28	4S	15E	S&K
A-622	21	11N	12E	S&K
A-623	4 or 9	9N	14E	S&K
A-624	21	1S	15E	S&K
A-625	24	1S	14½E	S&K
A-626	24	11N	12E	S&K
A-627	15	2S	15E	S&K
A-628	19	8N	10E	S&K
A-629	22	3N	17E	S&K
A-630	7	1S	15E	S&K
A-631	35	11N	13E	S&K
A-632	25?	7N	19E	S&K
A-633	5,8?	1S	14E	S&K

GRAHAM COUNTY

Map No.	Location Section	 Township	 Range	Data Source
A-200	33	7S	21E	S&K
A-201	20	10S	25E	S&K
A-202	6	9S	26E	S&K
A-203	28	5S	21E	S&K
A-204	9	5S	21E	S&K
A-205	28	7S	21E	S&K
A-206	23	8S	28E	S&K
A-207	14	7S	21E	S&K
A-208	9	8S	28E	S&K
A-209	29	11S	26E	S&K
A-210	13	11S	25E	S&K
A-211	24	11S	26E	S&K
A-212		9S	25E	S&K
A-213	28	7S	21E	S&K
A-214	21	8S	28E	S&K
A-215	16	7S	21E	S&K
A-216	22	8S	28E	S&K
A-217	22	8S	28E	S&K
A-218	5	10S	26E	S&K
A-219	28	7S	21E	S&K
A-220	20	10S	25E	S&K
A-221	33	2S	22E	S&K
A-222	30	8S	28E	S&K
A-223	35?	1S	19E	S&K

GREENLEE COUNTY

Map No.	Location Section	 Township	 Range	Data Source
A-250		3S	29E	S&K
		4S	29E	S&K

MARICOPA COUNTY

Map No.	Location Section	 Township	 Range	Data Source
A-500	19	7S	1W	S&K
A-501	12	6N	5E	S&K
A-502	13, 14	6N	8W	
	24, 18, 19, 20	6N	7W	S&K
A-503		4N	9W	S&K
A-504	14?	6N	7W	S&K
A-505		7N	5W	S&K
A-506	10	6N	4E	S&K
A-507	Lat33°58'48"	Long111°45'15"		
A-508		7N	6E	S&K
A-509	21, 24	1S	3W	S&K
A-510	36	2S	10W	S&K
A-511	19, 20	7N	2W	S&K
A-512	9	4N	5E	S&K
A-513	13, 14	6N	8W	S&K
A-514	32 or 33	7N	3E	S&K
A-515	1, 6?	7N	5-6E	S&K
A-516	4	4N	5E	S&K
A-517		7N?	3W?	S&K
A-518	29	3N	9E	S&K
A-520	21, 22	6N	8W	S&K
A-521	33	7N	5E	S&K
A-522	28	3N	5E	S&K
A-523	10	2S	4W	S&K
A-524	31	1S	3W	S&K
A-525	9	3N	8E	S&K
A-527	14, 13, 24	6N	8W	S&K
	19, 20	6N	7W	S&K
A-528	13, 18	2N	11, 12E	S&K

MOHAVE COUNTY

Map No.	Location Section	 Township	 Range	Data Source
A-100	4	22N	17W	S&K
A-101	33	28N	20W	S&K
A-102	35	21N	13W	S&K
A-103	32, 33	29N	22W	S&K
	4, 5	28N	22W	S&K
A-104	15	11N	14W	S&K
A-105	31	23N	17W	S&K
A-106	6	22N	17W	S&K

MOHAVE COUNTY (cont)

	Location			
Map No.	Section	Township	Range	Data Source
A-107	13?	12N?	13W?	S&K
A-108	35	17N	12W	S&K
A-109	7	22N	17W	S&K
A-110	31,32	23N	17W	S&K
	6,8	22N	17W	S&K
	12	22N	18W	S&K
A-111	18	22N	17W	S&K
A-112	25	33N	10W	S&K
A-113	28	11N	14W	S&K
A-114	23	30N	20W	S&K
A-115	1,2	32N	11W	S&K
A-116	1,2	32N	11W	S&K
A-117	14	32N	10W	S&K
A-118	16	33N	14W	S&K
A-119	9	22N	17W	S&K
A-120	21,22	30N	20W	S&K
A-121	5	22N	17W	S&K
A-122	28	40N	6W	S&K
A-123	12	19N	15W	S&K
A-124	13	22N	18W	S&K
A-125	31	23N	17W	S&K
A-126	21?	40N	16W	S&K
A-127	30	22N	17W	S&K
A-128	7	39N	3W	S&K
A-129	18	22N	17W	S&K
A-130	7	22N	17W	S&K
A-131	25-26	26N	11W	S&K
A-132	26	37N	5W	S&K
A-133	13	32N	8W	S&K
A-134	10,14	28N	16W	S&K
A-135	27	22N	17W	S&K
A-136	4	38N	6W	S&K
A-137	12	22N	18W	S&K
A-138	4	36N	16W	S&K
A-139	31	29N	21W	S&K
A-140	8	22N	17W	S&K
A-141	6	41N	3W	S&K
A-142	14	39N	4W	S&K
A-143	22	40N	6W	S&K
A-144	23	30N	18W	S&K
A-145	15	13N	12W	S&K
A-146	6	41N	3W	S&K
A-147	6	39N	3W	S&K
A-148	36	12N	13W	S&K
A-149	18	30N	20W	S&K
A-150	18	22N	17W	S&K
A-151	29	14N	12W	S&K

MOHAVE COUNTY (cont)

	Location			
Map No.	Section	Township	Range	Data Source
A-152	31	22N	17W	S&K
A-153	22	12N	13W	S&K
A-154	12	22N	18W	S&K
A-156	1	23N	14W	S&K
A-157	6	22N	17W	S&K
A-158	6	22N	17W	S&K
A-159	6	22N	17W	S&K
A-160	24	40N	6W	S&K
A-161	25	40N	6W	S&K
A-162	33	30N	22W	S&K
A-163	7	11N	13W	S&K
A-164	23	33N	10W	S&K
A-165	16	36N	13W	S&K
A-166	9	33N	14W	S&K
A-167	16	33N	11W	S&K
A-168		21N?	18W?	S&K
A-169	4	13N	12W	S&K
A-170	32	23N	17W	S&K
A-171	17	11N	17W	S&K
A-172	28, 29 32, 33	28N	10W	S&K
A-173	10	38N	15W	S&K
A-174	5	18N	20W	S&K
A-175	16	20N	13W	S&K
A-176	33	23N	17W	S&K
A-177	15	22N	17W	S&K
A-178	22?	40N	16W	S&K
A-179	2	27N	17W	B
A-180	8	30N	20W	B
A-181	8	29N	17W	B
A-182	12, 13	29N	21W	B
A-183	6	22N	17W	B

PIMA COUNTY

	Location			
Map No.	Section	Township	Range	Data Source
A-800	34, 35	17S	11E	S&K
A-801	23	17S	10E	S&K
A-802	16	18S	11E	S&K
A-803	23	18S	15E	S&K
A-804	36, 31	14S	2, 3E	S&K
A-805	13	14S	2E	S&K
A-806	34	17S	11E	S&K
A-807	23	15S	18E	S&K
A-808	33	12S	14E	S&K
A-809	17	15S	13E	S&K
A-810	14	13S	18E	S&K
A-811	2	17S	8E	S&K

PIMA COUNTY (cont)

Map No.	Location Section	 Township	 Range	Data Source
A-812	14,15,22 23,26,27 16,19, 9 10, 7, 8 18,20	16S	12E	S&K
A-813	34	17S	11E	S&K
A-814	8,16,17	18S	12E	S&K
A-815	5	21S	10E	S&K
A-816	21	11S	18E	S&K
A-817	8	17S	11E	S&K
A-818	36	17S	11E	S&K
A-819	26	21S	11E	S&K
A-820	31	17S	7E	S&K
A-821	24	18S	15E	S&K
A-822	33	12S	14E	S&K
A-823	10	18S	11E	S&K
A-824	5,8	18S	11E	S&K
A-825	11,14	15S	2E	S&K
A-826	6	21S	7E	S&K
A-827	9	18S	12E	S&K
A-828	20	11S	16E	S&K
A-829	19	19S	15E	S&K
A-830	5,6	16S	17E	S&K
A-831	13	12S	7E	S&K
A-832	32	21S	10E	S&K
A-833	30	17S	11E	S&K
A-834	21	20S	7E	S&K
A-835	21	11S	18E	S&K
	28	11S	18E	S&K
A-836	26	16S	8E	S&K
A-837	5,6	18S	13E	S&K
A-838	15	19S	18E	S&K
A-839	24	14S	2E	S&K
A-840	10	13S	18E	S&K
A-841	15	13S	18E	S&K
A-842	10,15	13S	18E	S&K
A-843	10	13S	18E	S&K
A-844	13,14,23,24	13S	18E	S&K
A-845	31	13S	19E	S&K

PINAL COUNTY

	Location			
Map No.	Section	Township	Range	Data Source
A-350	19	1S	14E	S&K
A-351	20	4S	13E	S&K
A-352	35	4S	12E	S&K
A-353	16	4S	13E	S&K
A-354	2	7S	17E	S&K
A-355	10	4S	13E	S&K
A-356	10	9S	5E	S&K
A-357	36	3S	7E	S&K
	31	3S	8E	S&K
A-358	16	3S	7E	S&K
A-359	23	8S	5E	S&K
A-360	10,11 14,15	8S	18E	S&K
A-362	10,11,15?	9S	16E	S&K
A-363	34	9S	3E	S&K
A-364	15	4S	13E	S&K
A-365	26,35	4S	11E	S&K
A-366	6	3S	13E	S&K
A-367	30	5S	15E	S&K
A-368	33	4S	13E	S&K

SANTA CRUZ COUNTY

	Location			
Map No.	Section	Township	Range	Data Source
A-700	12,13	21S	14E	S&K
A-701	1	23S	11E	S&K
A-702	27,28 33,34	21S	15E	S&K
A-703	17,20	21S	15E	S&K
A-704	23	22S	17E	S&K
A-705	19	20S	14E	S&K
A-706	29	21S	15E	S&K
A-707	19	20S	14E	S&K
A-708	33	20S	15E	S&K
A-709	20	22S	10E	S&K
A-710	5	24S	12E	S&K
A-711	16	21S	15E	S&K
A-712	?	22S?	12E?	S&K
A-713	20-29	22S	11E	S&K
A-714	4,5	24S	12E	S&K
A-715	20	22S	10E	S&K
A-716	32-33	23S	11E	S&K
A-717	5	24S	12E	S&K
A-718	35	22S	10E	S&K
A-719	3	24S	12E	S&K
A-720	2	24S	12E	S&K
A-721	31	23S	12E	S&K
A-722	23	22S	10E	S&K

SANTA CRUZ COUNTY

	Location			
Map No.	Section	Township	Range	Data Source
A-723	6	23S	11E	S&K
A-724	5,8	24S	12E	S&K
A-725	36	22S	10E	S&K

YAVAPAI COUNTY

	Location			
Map No.	Section	Township	Range	Data Source
A-400	11	8N	3W	S&K
A-401	9,10,11 12,3,14,15	11N	10W	S&K
A-402	3	8N	1E	S&K
A-403	4	8N	1W	S&K
A-404	4	14N	9W	S&K
A-405	28	8N	1W	S&K
A-406	4?	8N	1W	S&K
A-407	11	9N	3W	S&K
A-409	8,16	11N	5W	S&K
A-410	27	14N	8W	S&K
A-411	23	10N	6W	S&K
A-412	2	8N	1W	S&K
A-413	?	14N	9W	S&K
A-414	14	14N	8W	S&K
A-415	1-16	8N	1E	S&K
A-416	25,26	12½N	2W	S&K
A-417	12,13	15N	2W	S&K
A-419	13	10N	1E	S&K
A-420	27,28	10N	1W	S&K
A-421	27	15N	9W	S&K
A-422	19	7N	2W	S&K
A-423	27	15N	9W	S&K
A-424	?	10N	6W	S&K
A-425	16,21	15N	9W	S&K
A-426	27	15N	9W	S&K
A-427	21	11N	1E	S&K
A-428	23	12N	6W	S&K
A-429	7	14N	9W	S&K
A-430	23?	8N?	3W?	S&K
A-431	30	11N	2E	S&K
A-432	17	14N	9W	S&K
A-434	26-27	12½N	3W	S&K
A-435		11N?	5W?	S&K
A-436	9	11N	10W	S&K
A-437	2	16N	1W	S&K
A-438	16,17 20,21	7N	2W	S&K
A-439	25,26,36	13N	3W	S&K

YAVAPAI COUNTY

Map No.	Location Section	Township	Range	Data Source
A-440	?	16-17N	3E	S&K
A-441	18,13	10N	2,3W	S&K
A-442	21	13N	3W	S&K
A-443		8N?	5W	S&K
A-444		10N	5W	S&K
A-445	24	17N	6W	S&K

YUMA COUNTY

Map No.	Location Section	Township	Range	Data Source
A-900	9,10 16,17,21	9S	20W	S&K
A-901	10,11	2S	20W	S&K
A-902	26	7N	13W	S&K
A-903	?	2S?	11W	S&K
A-904		7S	18W	S&K
A-905	35	5N	14W	S&K
A-906	?	8N	12W	S&K
A-910	6,7	8S	18W	S&K
	1,12	8S	19W	S&K
A-911	2	8S	19W	S&K
A-912		6N?	17W?	S&K
A-913	16	12S	16W	S&K
A-914	5	6N	13W	S&K
A-915	2,12	8S	19W	S&K
A-916	13	6N	18W	S&K
A-917	10	8S	19W	S&K
A-918	25	7S	19W	S&K
A-920	1	4S	23W	S&K
A-921	3-10	9S	20W	S&K
A-922	36	4N	20W	S&K
A-923	7	6N	17W	S&K
A-924	22	4N	20W	S&K
A-925	32	3N	20W	S&K
A-926	25	4N	20W	S&K
A-927	2	8S	19W	S&K
A-928	31	7S	18W	S&K

CALIFORNIA (Map C-2)

FRESNO COUNTY

	Location			
Map No.	Section	Township	Range	Data Source
C-100	22	12S	26E	PRR 998
C-101	26,35	12S	20E	PRR 997
C-102	16	15S	12,22E	PRR 996
C-103	11	11S	24E	PRR 994

IMPERIAL COUNTY

	Location			
Map No.	Section	Township	Range	Data Source
C-900	1,2	9S	15E	PRR 1004
	2,11	9S	14E	PRR 1004
C-901	36	12S	19E	PRR 1003
C-902	24	12S	19E	PRR 1002
C-903	14	12S	19E	PRR 1007
C-904	18,19	15S	21E	PRR 1005
C-905	14	14S	11E	PRR 1008
C-906	12	9S	14E	PRR 999
C-907	12	10S	15E	PRR 1000
C-908	3,4	12S	19E	PRR 1001

INYO COUNTY

	Location			
Map No.	Section	Township	Range	Data Source
C-200	25	20S	37E	PRR 1013
C-201	7	18S	44E	PRR 1012
C-202	14,23	19S	40E	PRR 1011
C-203		15S	40E	PRR 1010
C-204	?	20S	45E	PRR 1020
C-205		18S	38E	PRR 1019
C-206	7,18	19S	38E	PRR 1017
C-207	13,14			
	32,24	19S	37E	PRR 1016
C-208	20?	8S	39E	PRR 1015
C-209	?	19S	38E	PRR 1028
C-210	18	19S	38E	PRR 1027
C-211	19	15S	37E	PRR 1026
C-212	19	15S	37E	PRR 1025
C-213	?	15S	36E	PRR 1023
C-214	10	13S	36E	PRR 1022
C-215	16	21S	45E	PRR 1021
C-216	25	19S	37E	PRR 1036
C-217	24,25	19S	37E	PRR 1034
C-218	12	22S	42E?	PRR 1033
C-219	14	15S	40E?	PRR 1032
C-220	13	13S	41E?	PRR 1031

INYO COUNTY

	Location			
Map No.	Section	Township	Range	Data Source
C-221	12	16S	41E	PRR 1044
C-222	13	19S	41E	PRR 1043
C-223	1,6	21S	37E	PRR 1042
C-224	25	20S	37E	PRR 1041
C-225	8	15S	42E	PRR 1039
C-226		23S	44E	PRR 1038
C-227	24,25	19S	37E ?	PRR 1037
C-228	18,19	19S	38E	PRR 1030
C-229	25	19S	37E	PRR 1029
C-230	3	21N	3E	B
C-231		23S	44E	B
C-232	29,30,31	22S	39E	B
C-233	1,2	14S	40E	B
C-234	10	14S	41E	B
C-235	23	18S	38E	B
C-236	21	16S	41E	B
C-237	6	21S	38E	B
C-238	35	21S	45E	B
C-239	35	21S	45E	B

KERN COUNTY

	Location			
Map No.	Section	Township	Range	Data Source
C-500	20	32S	23E	PRR 1046
C-501	24	27S	34E	PRR 1045
C-502	10	9N	22W	PRR 1040
C-503	26	26S	31E	PRR 1054
C-504	26	30S	34E	PRR 1053
C-505	11?	29S	20E	PRR 1052
C-506	19	27S	36E	PRR 1051
C-507	9	32S	35E	PRR 1050
C-508	33	31S	22E	PRR 1049
C-509	35	32S	23E	PRR 1062
	31,32	12N	24W	PRR 1062
C-510	30	27S	32E	PRR 1061
C-511	1	30S	36E	PRR 1060
C-512	1	30S	36E	PRR 1059
C-513	33	12N	24W	PRR 1058
C-514	34,35	26S	18E	PRR 1057
C-515	28	27S	32E	PRR 1048
C-516	19?	31S	36E	PRR 1047
C-517	21	11N	20W	PRR 1056
C-518	20	27S	36E	PRR 1055
C-519	9,10	9N	13W	PRR 1067
C-520	7	27S	30E	PRR 1068
	12	27S	31E	PRR 1068
C-521	30	29S	37E	
C-522	4	11N	24E	PRR 1066

KERN COUNTY

Map No.	Location			Data Source
	Section	Township	Range	
C-523	17	27S	33E	PRR 1065
C-524	9	9N	13W	PRR 1076
C-525	36	10N	12W	PRR 1075
C-526	10	9N	13W	PRR 1074
C-527	4	9N	13W	PRR 1073
C-528	26	11N	8W	PRR 1072
C-529	16	10N	13W	PRR 1083
C-530	36	10N	13W	PRR 1082
C-531	?	11N	8W	PRR 1081
C-532	10 or 11	9N	6W	PRR 1080
C-533	34	32S	35W	PRR 1079
C-534	36	10N	13W	PRR 1092
C-535	1	29S	39E	PRR 1091
C-536	10	30S	36E	PRR 1096
C-537	9	10N	13W	PRR 1089
C-538	35	10N	13W	PRR 1088
C-539	9	10N	13W	PRR 1087
C-540	6	10N	12W	PRR 1086
C-541	11	10N	13W	PRR 1085
C-542	36	10N	13W	PRR 1093
C-543	30	27S	40E	PRR 1094
C-544	26	28S	40E	PRR 1077
C-545	26	28S	40E	PRR 1078
C-546	25	10N	13W	PRR 1070
C-547	25	10N	13W	PRR 1071
C-548	17	27S	32E	PRR 1063
C-549	12,13	27S	18E	PRR 1064
C-550	18	27S	32E	PRR 1108
C-552	22	27S	32E	PRR 1106
C-554	?	31S	36E	PRR 1116
C-55	8	30S	32E	PRR 1115
C-556	11	9N	13W	PRR 1114
C-557	9	28S	32E	PRR 1112
C-558	23	27S	31E	PRR 1111
C-559	30	27S	34E	PRR 1124
C-560	18	30S	32E	PRR 1123
C-561	26	32S	38E	PRR 1122
C-562	35	30S	38E	PRR 1121
C-563	10	9N	22W	PRR 1120
C-564	28	30S	34E	PRR 1119
C-565	3	30S	21E	PRR 1132
C-566	30	27S	34E	PRR 1131
C-567	30	28S	32E	PRR 1130
C-568	4	9N	14W	PRR 1129
C-569	16	32S	35E	PRR 1128
C-570	6	31S	34E	PRR 1139

KERN COUNTY

	Location			
Map No.	Section	Township	Range	Data Source
C-571	6	29S	38E	PRR 1138
C-572	1,32	27S	18E	PRR 1137
C-573	6	11N	8W	PRR 1136
C-574	26	27N	35E	PRR 1135
C-575	8	11N	14W	PRR 1110
C-576	23	27S	35E	PRR 1109
C-577	27,28	28S	31E	PRR 1118
C-578	19	27S	32E	PRR 1117
C-579	1	28S	31E	PRR 1126
C-580	27	27S	29E	PRR 1125
C-581	4	29S	35E	PRR 1134
C-582	29	32S	23E	PRR 1127
C-583	28	31S	36E	PRR 1133
C-584	26	32S	38E	B
C-585	24	31S	38E	B
C-586	2	30S	40E	B
C-587	13	29S	37E	B
C-588	1	29S	39E	B
C-589	36	28S	40E	B

MONO COUNTY

	Location			
Map No.	Section	Township	Range	Data Source
C-301	18	3S	31E	PRR 1202
C-302	36?	5N	27E	PRR 1204
C-303	18	3S	31E	PRR 1203
C-304	10	4S	33E	PRR 1213
C-305	34	4S	31E	PRR 1212
C-306	20	7N	24E	PRR 1211
C-307	5,6,7,8	5N	22E	PRR 1210
C-308	19	6N	23E	PRR 1209
C-309	?	1N	31E	PRR 1208
C-310		5S?	37E?	PRR 1207
C-311	24	6N	23E	PRR 1206
C-312	2	4S	35E	PRR 1220
C-313	23,24	6N	23E	PRR 1219
C-314	17	6N	23E	PRR 1218
C-315	21?	4S	27E	PRR 1217
C-316	34	4S	31E	PRR 1216
C-317	22	2S	33E	PRR 1215
C-318	22	2S	33E	PRR 1214

RIVERSIDE COUNTY

Map No.	Location Section	Township	Range	Data Source
C-700	9,15,16	2S	11E	PRR 1250
C-701	2	2S	9E	PRR 1249
C-702	35	5S	12E	PRR 1248
C-703	22	6S	13E	PRR 1247
C-704	4 or 32	2 or 3?	12E	PRR 1246
C-705	1	2S	9E	PRR 1245
C-706	31,32	5S	10E	PRR 1258
C-707	18	6S	21E	PRR 1257
C-708	1,2	2S	9E	PRR 1256
C-709		5S?	11E?	PRR 1254
C-710	30	4S	2W	PRR 1266
C-711	15,16	2S	4W	PRR 1265
C-712	1	6S	15E	PRR 1261
	26	6S	14E	PRR 1261
C-713	5	8S	21E	PRR 1252
C-714	5	8S	21E	PRR 1251
C-715	1,14	7S	14E	PRR 1259
C-716	1	7S	14E	PRR 1260
C-717	15	6S	13E	PRR 1273
C-718	7	7S	15E	PRR 1272
C-719	12	5S	22E	PRR 1271
C-720	24,13	5S	23E	PRR 1270
C-721	21,22	7S	21E	PRR 1280
C-722	19	6S	21E	PRR 1279
C-723	13	6S	20E	PRR 1278
C-724	19,20,21 28,29,30	7S	21E	PRR 1277
C-725	28	7S	21E	PRR 1376
C-726	7	4S	11E	PRR 1284
C-727	35	3S	8E	PRR 1283
C-728	20	6S	7E	PRR 1282
C-730	23	3S	1W	PRR 1276
C-731	21	2S	3E	PRR 1275
C-732	28	7S	21E	PRR 1274

SAN BERNARDINO

Map No.	Location Section	Township	Range	Data Source
C-600	18	8N	7W	PRR 1287
C-601		2N	12E	PRR 1294
C-602	13	1N?	7E	PRR 1293
C-603	19	6N	13E	PRR 1292
C-604	18	6N	13E	PRR 1291
C-605	4	2N	1E	PRR 1290
C-606	14	11N	7W	PRR 1289
C-607	33	2N	2W	PRR 1302
C-608	17	16N	14E	PRR 1300

SAN BERNARDINO (cont.)

	Location			
Map No.	Section	Township	Range	Data Source
C-609		17N?	11E?	PRR 1299
C-610	24	10N	1E	PRR 1298
C-611	12	6N	1W	PRR 1297
C-612	33	2N	1E	PRR 1296
C-613	8,5?	2N	12E	PRR 1295
C-614	11,12	10N	3E	PRR 1288
C-615	17,18	10N	2E	PRR 1301
C-616	6	10N	1E	PRR 1308
	31	11N	1E	PRR 1308
C-617	12	11N	7W	PRR 1304
C-618		13N	10E	PRR 1316
C-619	19	7N	1E	PRR 1315
C-620	12	6N	1W	PRR 1314
C-621	12	9N	18E	PRR 1313
C-622	19	1N	8E	PRR 1323
C-623	25,35	1S	8E	PRR 1321
C-624	22,27	1S	9E	PRR 1320
C-625		6N	18E	PRR 1319
C-626	29	15½N	14E	PRR 1327
C-627	31	2N	7E	PRR 1326
C-628	7,8	1S	1E	PRR 1339
C-629	21	10N	3E	PRR 1338
C-630	18	8N	7W	PRR 1337
C-631	8,17	16N	13E	PRR 1334
C-632	7,8,17	16N	13E	PRR 1333
C-633	18	2N	4E	PRR 1325
C-634	7	11N	14E	PRR 1311
C-635	18	11N	14E	PRR 1310
C-636	1	4N	5E	PRR 1303
C-639	16	3N	16E	PRR 1309
C-640	33,34	13N	9E	PRR 1307
C-641	30,36	1S	3E	PRR 1346
C-642	8,16	4S?	2W?	PRR 1345
C-643	25	10N	6W	PRR 1344
C-644		29,30S	41W?	PRR 1343
C-645		30S	43W?	PRR 1342
C-646	30	29S	40E	PRR 1341
C-647	26	13N	12E	PRR 1354
C-648	29	4N	7W	PRR 1353
C-649	32?	12N	17E	PRR 1352
C-650	16	11N	20E	PRR 1351
C-651	8	1S	1E	PRR 1350
C-652	21	28S	41E	PRR 1349
C-653	1	15N	10E	PRR 1362
C-654	35	1N	8E	PRR 1361
C-655	23	3N	4E	PRR 1360
C-656	34,35	14N	15E	PRR 1359

SAN BERNARDINO (cont.)

Map No.	Location Section	Township	Range	Data Source
C-657	4	29S	41E	PRR 1358
C-658	11	28S	41E	PRR 1357
C-659	?	15N	11E	PRR 1370
C-660	33	8N	3E	PRR 1369
C-661	31	6N	13E	PRR 1367
C-662	9	15N	11E	PRR 1366
C-663	30	32S	42E	PRR 1365
C-664	15	9N	6W	PRR 1373
C-665	15	16N	12E	PRR 1372
C-666	?	15N	11E	PRR 1371
C-667	33,28	2N	2E	PRR 1340
C-668	25,36	3N	1E	PRR 1348
C-669	19,20	2N	3E	PRR 1347
C-670	25	28S	41E	PRR 1356
C-671	18	1S	5E	PRR 1355
C-672	22	9N	14E	PRR 1363
C-673		30S	41E	B
C-674	30	29S	40,41E	B
C-675	15	32S	41E	B
C-676	14	11N	7W	B
C-677	2,4,5,6 8,10,22	11N	7W	B
C-681	7,18,19	13N	9E	B
C-686	31	28S	41E	B
C-687	23?	11N	2W	B

TULARE COUNTY

Map No.	Location Section	Township	Range	Data Source
C-400	13,14	15S	27E	PRR 1415
C-401	16	24S	31E	PRR 1414
C-402	11	17S	29E	PRR 1413
C-403	11	24S	35E	PRR 1412
C-404	21	24S	35E	PRR 1411
C-405	35	22S	32E	PRR 1410
C-406	3	16S	25E	PRR 1423
C-407	24	23S	32E	PRR 1422
C-408	12	17S	29E	PRR 1421
C-409	14	17S	29E	PRR 1420
C-410	23	23S	28E	PRR 1419
C-411	17	24S	31E	PRR 1418
C-412	11	16S	26E	PRR 1424
C-413	2	21S	29E	PRR 1425
C-414	28,29	23S	33E	PRR 1417
C-415	25	23S	32E	PRR 1416

IDAHO (Map C-3)

BLAINE COUNTY

	Location			
Map No.	Section	Township	Range	Data Source
I-100	18?	3N	17E	PRR 2474
I-101	19	1N	17E	PRR 2473
I-102	20	1N	17S	PRR 2472
I-103		6N	13 or 14E	PRR 2471
I-104	13	1N	16E	PRR 2470
I-105	8,9,16,17	1N	17E	PRR 2469
I-106	7,8	1N	17E	PRR 2476

BONNER COUNTY

	Location			
Map No.	Section	Township	Range	Data Source
I-200	26	58N?	2E	PRR 2483
I-201	14	56N	1W	PRR 2482
I-202	12	59N	4W	PRR 2481
I-203	6	59N	1E	PRR 2480
I-204	34	55N	3W	PRR 2479
I-205	26	61N	4W	PRR 2485
I-206	10	62N	4W	M
I-207	10	62N	4W	B

BOUNDARY COUNTY

	Location			
Map No.	Section	Township	Range	Data Source
I-300	25	65N	1W	PRR 2490
I-301	13	65N	1W	PRR 2489
I-302	5,6,7,8	64N	1W	PRR 2488
I-303	11,12,13,14	65N	1W	PRR 2487
I-304	12,13	65N	1W	PRR 2486
I-305	7?	60N	1E	PRR 2493
I-306	30?	61N?	3W?	B
I-307	14	62N	1W	B
I-308	7?	60N	2E?	B
I-309	21	60N	1E	B
I-310	30	61N	3W	M
I-311	28	61N	3E	M

BUTTE COUNTY

	Location			
Map No.	Section	Township	Range	Data Source
I-450	12,13	7N	28E	PRR 2496
I-451	14,15	3N	24E	PRR 2494

CASSIA COUNTY

	Location			
Map No.	Section	Township	Range	Data Source
I-350		15S	24E	PRR 2503
I-351		12S	25E	PRR 2501

CASSIA COUNTY (cont.)

	Location			
Map No.	Section	Township	Range	Data Source
I-352		12S	24E	PRR 2500
I-353	10,28			
	26,25	16S	21E	B
I-354	25,31	16S	24E	B
I-355	36	15S	23E	B
I-356	36	15S	23E	B
I-357	6,8	15S	24E	B
I-358	30,31,32	15S	24E	B
I-359	7	13S	25E	B
I-360	7,8,9	13S	25E	B
I-361	23	13S	24E	B
I-362	10	16S	21E	B
I-363	36	15S	23E	M

CUSTER COUNTY

	Location			
Map No.	Section	Township	Range	Data Source
I-500	10	11N	13E	PRR 2513
I-501	11	11N	13E	PRR 2512
I-502	16	11N	16E	PRR 2511
I-503	10	11N	16E	PRR 2510
I-504	11,14	11N	16E	PRR 2509
I-505	7,8	11N	14E	PRR 2508
I-506	10	11N	13E	PRR 2519
I-507	14	6N	19E	PRR 2517
I-508	22	11N	13E	PRR 2516
	33	12N	13E	PRR 2516
I-509	4,5,8,9	11N	14E	PRR 2515
I-510	29	9N	15E	PRR 2521
I-511	1,2	11N	13E	PRR 2514
I-512	14,15,10	11N	14E	B
I-513	16	11N	14E	B
I-514	13,21	11N	14E	B
I-515	15,16	11N	14E	B
I-516	11,12,13,14	11N	14E	B
I-517	15,16	11N	14E	B
I-518	32 or 33	17N	13E	B
I-519	13	11N	14E	B

IDAHO COUNTY

	Location			
Map No.	Section	Township	Range	Data Source
I-600		29N	5E	PRR 2528
I-601		29N	5E	PRR 2527
I-602	32	27N	7E	PRR 2462
I-603	11	30N	7E	PRR 2461
I-604	36	31N	7E	PRR 2460

IDAHO COUNTY (cont)

Map No.	Location Section	Township	Range	Data Source
I-605	2,11,13 12,24,25	29N	8E	PRR 2532
I-606	21,27	24N	3E	PRR 2531
I-607	10	26N	6E	PRR 2530
I-608	1,2	30N	7E	PRR 2529
I-609	30,31	29N	8E	M
I-611	11	25N	8E	B
I-612	10	25N	8E	B
I-613	11	23N	5E	B
I-614	27	23N	6E	B
I-615	4	22N	7E	B
I-616	17,18	22N	5E	B

KOOTENAI COUNTY

Map No.	Location Section	Township	Range	Data Source
I-150	12,13	49N	3W	PRR 2535
I-150	18	49N	2W	PRR 2535
I-151	6	52N	3W	PRR 2534

LEMHI COUNTY

Map No.	Location Section	Township	Range	Data Source
I-740	9	20N	22E	PRR 2587
I-741		25N	18E	PRR 2574
I-742	31	26N	21E	PRR 2567
I-744	35,36	18N	25E	PRR 2611
	2	17N	25E	PRR 2611
I-745	35,36	24N	18E	PRR 2610
I-746	21	21N	21E?	PRR 2609
I-747	33	24N	20E	PRR 2607
I-748	25	18N	17E	PRR 2606
I-749	15	18N	25E	PRR 2616
I-750	6	19N	25E	PRR 2615
I-751	1	13N	24E	PRR 2614
I-752	26	24N	20E	PRR 2613
I-753	26	24N	20E	PRR 2612
I-754	18	20N	22E	PRR 2551
I-755	16	23N	18E	B
I-756	5	17N	14E	B
I-700	18	24N	20E	PRR 2542
I-701	21	24N	20E	PRR 2541
I-703	15	19 or 18N?	25E	PRR 2539
I-704		24N	20E	PRR 2538
I-705	20	24N	21E	PRR 2549
I-706	25	16N	20E	PRR 2548
I-707	28	19N	23E	PRR 2547
I-708	29	19N	25E	PRR 2546

LEMHI COUNTY

		Location		
Map No.	Section	Township	Range	Data Source
I-709	16	19N	25E	PRR 2545
I-710	26,27	23N	23E	PRR 2556
I-711	2 or 11	19N	24E	PRR 2555
I-712	?	20N	24E	PRR 2554
I-713	7	20N	22E	PRR 2553
I-714	12	20N	21E	PRR 2552
I-715	18	24N	20E	PRR 2543
I-716	26	23N	21E	PRR 2544
I-717		24N	19,20E	PRR 2561
I-718	4	24N	19E	PRR 2573
I-719	5	24N	19E	PRR 2572
I-720	26,35	24N	20E	PRR 2571
I-721	27	23N	21E	PRR 2569
I-722	31	26N	21E	PRR 2568
I-723	14	22N	21E	PRR 2586
I-724	9	18N	24E	PRR 2584
I-725	32	25N	19E	PRR 2576
I-726	13	26N	20E	PRR 2594
I-727	32	25N	19E	PRR 2593
I-728	21	26N	21E	PRR 2592
I-729	10	19N	25E	PRR 2591
I-730	15	19N	25E	PRR 2590
I-731	14	22N	21E	PRR 2589
I-732	13	26N	20E	PRR 2603
I-733	35,36	24N	18E	PRR 2602
I-734	7	25N	21E	PRR 2601
I-735	14 or 15	16S	28E	PRR 2598
I-736	6	17N	17E	PRR 2597
I-737	2	19N	22E	PRR 2596
I-738	27	19N	25E	PRR 2595
I-739	2,11	19N	22E	PRR 2588

SHOSHONE COUNTY

		Location		
Map No.	Section	Township	Range	Data Source
I-400	16,17	48N	3E	PRR 2623
I-401	20,28,29 30,32,33	48N	4E	PRR 2622
I-402	16	48N	3E	PRR 2621
I-403	1,2	47N	5E	PRR 2627
	5,6	47N	6E	PRR 2627
I-404	36	50N	2E	PRR 2626
	31	50N	3E	PRR 2626
I-405	11-12-13-14	43N	2E	PRR 2625
I-406	11-12-13-14	43N	2E	PRR 2625
I-407	9,10	46N	2E	PRR 2624
I-409	29	48N	4E	PRR 2636
I-410	24	48N	3E	M

MONTANA (Map C-4)

LINCOLN COUNTY

Map No.	Location Section	 Township	 Range	Data Source
M-500	28?	31N	30W	PRR 3121
M-501	26,27	31N	30W	PRR 3120

MINERAL

Map No.	Location Section	 Township	 Range	Data Source
M-201	11	18N	28W	PRR 3163
M-202	19	19N	30W	PRR 3158
M-203	18	19N	30W	PRR 3168
M-204	31	18N	26W	PRR 3169
M-205	18?	19N	30W	PRR 3168

RAVALLI COUNTY

Map No.	Location Section	 Township	 Range	Data Source
M-100	27	1N	18W	PRR 3278
M-101	35	5N	20W	PRR 3277
M-102	15	2N	19W	PRR 3276
M-103	8	3S	22W	PRR 3275
M-104	14	3N	17W	PRR 3290
M-105	17,18	3N	18W	PRR 3288
M-106	33?	5N	20W	PRR 3281
M-107	9	3S	22W	M
M-108	22	2N	21W	M
M-110	10	4S	22W	B
M-111	34	5N	20W	B

SANDERS COUNTY

Map No.	Location Section	 Township	 Range	Data Source
M-400	11,14,33,24	24N	31W	PRR 3210
M-401		24N	34W	M

NEVADA (Map C-5)

CLARK COUNTY

Map No.	Location Section	Township	Range	Data Source
N- 16	13, 24	18S	70E	G
N- 17	30	18S	71E	G
N- 18	25	18S	70E	G
N- 19	35?	18S	70E	G
N- 20	2	19S	70E	G
N- 21	2	19S	70E	G
N- 22	3?	19S	70E	G
N- 23	32	18S	70E	G
N- 24	12	19S	69E	G
N- 25	21	19S	70E	G
N- 26		19S	70E	G
N- 27	8,5	15S	67E	G
N- 28		15-16S	66E	G
N- 29		16S	67E	G
N- 30	20	16S	67E	G
N- 31	16	16S	67E	G
N- 33	12	23S	60E	G
N- 34	2	23S	60E	G
N- 35	1	23S	60E	G
N- 36	4, 15, 16, 28	23S	60E	G
N- 37	13	23S	60E	G
N- 38	24	23S	60E	G
N- 39	25	23S	60E	G
N- 40	25	23S	60E	G
N- 41	25	23S	60E	G
N- 42	36	23S	60E	G
N- 43	36	23S	60E	G
	2	24S	60E	G
N- 44	11	24S	60E	G
N- 45	8	24S	60E	G
N- 46	29,30,31,32	24S	60E	G
N- 47	16,21	24S	60E	G
N- 48	30	24S	60E	G
N- 49	19	24S	60E	G
N- 50	24,25	24S	59E	G
N- 51	24	24S	59E	G
N- 52	6	25S	60E	G
N- 53	14	24S	58E	G
N- 54	12	23S	57E	G
N- 55	36?	23S	56E	G
N- 56	1	24S	56E	G
N- 57	1	24S	56E	G
N- 58	2	24S	56E	G
N- 59	6	24S	57E	G
N- 60	4	24S	57E	G
N- 61	35	23S	57E	G

CLARK COUNTY

	Location			
Map No.	Section	Township	Range	Data Source
N- 63	23	24S	57E	G
N- 64	26	24S	57E	G
N- 65	26	24S	57E	G
N- 66	26	24S	57E	G
N- 67	26	24S	57E	G
N- 68	26	24S	57E	G
N- 69	26	24S	57E	G
N- 70	27,34	24S	27E	G
N- 71	34	24S	57E	G
N- 72	35	24S	57E	G
N- 73	35	24S	57E	G
N- 74	36	24S	57E	G
N- 76	20	24S	58E	G
N- 77	20	24S	58E	G
N- 78	20	24S	58E	G
N- 79	20	24S	58E	G
N- 80	21	24S	58E	G
N- 81	5	25S	58E	G
N- 82	31	24S	58E	G
N- 83	32	24S	58E	G
N- 84	32	24S	58E	G
N- 85	1	25S	58E	G
N- 86	2	25S	58E	G
N- 87	3,4	25S	58E	G
N- 88	23	25S	58E	G
N- 89	13	25S	58E	G
N- 90	13	25S	58E	G
N- 91	27	25S	58E	G
N- 92	20	25S	58E	G
N- 93	20	25S	58E	G
N- 94	18	25S	58E	G
N- 95	11	25S	57E	G
N- 96	11	25S	57E	G
N- 97	13	25S	57E	G
N- 98	5	26S	58E	G
N- 99	9?	26S	58E	G
N-101	21	28S	61E	G
N-102	22	28S	61E	G
N-103	22,27	28S	61E	G
N-104	29?	28S	61E	G
N-105	32	28S	61E	G
N-106	3,10	29S	61E	G
N-107	6 or 7	13S	64E	G
N-108	16?	15S	70E	G
N-109	24	18S	61E	G
N-110	25 or 26?	20S	62E	G
N-111	10,12,14	20S	63E	G
N-112		19,20S	66E	G

CLARK COUNTY (cont.)

	Location			
Map No.	Section	Township	Range	Data Source
N-113	15?	19S	67E	G
N-114	18	20S	70E	G
N-115	35?	25S	63E	G
N-116	36?	25S	64E	G
N-117	14?	26S	63E	G
N-118	4	27S	64E	G
N-119	7?	26S	64E	G
N-120	32	27S	60E	G
N-121	3	32S	64E	G
N-500	10	25S	63E	B

ELKO COUNTY

	Location			
Map No.	Section	Township	Range	Data Source
N-131	25,36	46N	53E	G
	19,30	46N	54E	G
N-132		46N	54E	G
N-133	2	45N	53E	G
N-134	1	45N	53E	G
N-135	5	45N	54E	G
N-137	33	46N	54E	G
N-138	27,34	46N	54E	G
N-139	26	46N	54E	G
N-140	35	46N	54E	G
N-142	19,20,29,30,31	45N	55E	G
N-143	18,21,28,33	45N	55E	G
N-147	16,17	45N	56E	G
N-148	3,4	44N	63E	G
N-149	35?	44N	63E	G
N-152	32	44N	66E	G
N-153	22 or 27	44N	66E	G
N-154	7	47E	70E	G
N-155	19	47N	?	G
N-156	9	29N	57E	G
N-157	16	29N	58E	G
N-159	19	44N	52E	G
N-161	23	37N	67E	G
N-163	24	32N	52E	G
N-164	34	32N	52E	G
N-165	19,24?	30N	52E	G
N-166	1	29N	52E	G
N-167		46N	53E	B
N-168	Lat40°21'58" Long115°05'01"			B
N-169	Lat40°30'39" Long115°39'12"			B
N-170	Lat40°35'05" Long115°43'32"			B

ESMERALDA COUNTY

	Location			
Map No.	Section	Township	Range	Data Source
N-173	14?	5N	38E	G
N-175	28	2N	36E	G
N-176	32	2N	36E	G
N-179	2 or 3?	1N	36E	G
N-180	3,10?	1N	36E	G
N-181	33	2N	37E	G
N-182	30,19	3N	42E	G
N-183	29	3N	42E	G
N-184	29,32	3N	42E	G
N-185	32	3N	42E	G
N-186	32	3N	42E	G
	6	2N	42E	G
N-187	32	3N	42E	G
	29	3N	42E	G
N-190		8S	41E	G
N-191	23,26	8S	40E	G
N-192	12 or 13	7S	41E	G
N-193	Lat37°18'14"	Long117°20'50"		
N-195		8S	42E	G
N-196		8S	42E	G
N-197	2?	8S	42E	G
N-198	1	4N	39E	G
N-199	7	3N	36E	G
N-200	23	1N	39E	G
N-202	32	1S	37E	G
N-203	32	2S	38E	G
N-206	25,36	4S	38E	G
N-207	35?	4S	40E	G
N-208	4	6S	40E	G

EUREKA COUNTY

	Location			
Map No.	Section	Township	Range	Data Source
N-209	28	34N	51E	G
N-210	12	18N	53E	G

LINCOLN COUNTY

	Location			
Map No.	Section	Township	Range	Data Source
N-249	22	7N	68E	G
N-250	15	7N	68E	G
N-251	16	7N	68E	G
N-253	3	2S	68E	G
N-254	9 or 10	2S	68E	G
N-255	4	2S	68E	G
N-260		1N	71E	G
N-261	32?	1N	68E	G
N-262	33?	1N	68E	G

LINCOLN COUNTY (cont.)

Map No.	Location Section	 Township	 Range	Data Source
N-263	18	3S	67E	G
N-264	36	3S	56E	G

NYE COUNTY

Map No.	Location Section	 Township	 Range	Data Source
N-331	24	14N	39E	G
N-332	3	13N	39E	G
N-333	13?	13N	36E	G
N-334	13?	13N	36E	G
N-336	13?	13N	36E	G
N-335	13?	13N	36E	G
N-337	1?	12N	45E	G
N-339	?	11N	45E	G
N-342	21 or 22?	10N	44E	G
N-343	27 or 23?	10N	44E	G
N-344	27?	10N	44E	G
N-346	28 or 29?	10N	44E	G
N-347	31,32	10N	44E	G
N-348	6?	9N	44E	G
N-349	20,29	9N	45E	G
N-350	33	6N	57E	G
N-351	33	6N	57E	G
N-352	6	3N	42E	G
	31	4N	42E	G
N-353	36	4N	41E	G
N-354	25	4N	41E	G
N-355	16	3N	42E	G
N-357	26	11S	46E	G
N-358	26	11S	46E	G
N-359	15	12S	46E	G
N-360	16	12S	46E	G
N-361	23	12S	47E	G
N-362	22	12S	47E	G
N-363	10	15N	48E	G
N-364	8	12N	34E	G
N-365	12?	10N	57E	G
N-366	25	10N	51E	G
N-367	28	10N	51E	G
N-372	1	3S	43E	G
N-373	18?	17S	54E	G
N-501	13	13S	47E	B
N-502	23	12S	47E	B
N-503	26	12S	46E	B
N-504	22	12S	47E	B

WHITE PINE COUNTY

	Location			
Map No.	Section	Township	Range	Data Source
N-438	2?	23N	63E	G
N-439	?	22N	62E	G
N-440	32	21N	62E	G
N-441		13N	69E	G
N-442	7 or 8?	12N	63E	G

UTAH (Map C-6)

BOX ELDER COUNTY

	Location			
Map No.	Section	Township	Range	Data Source
U-300	31	8N	1W	PRR 5052
U-301		8N	3W	PRR 5050
U-302		7,8N	1,2W	PRR 5049
U-303		13N	18W	FileSL140
U-304		13N	14W	PRR 5061
U-305	10	7N	2W	PRR 5060
U-306	2	9N	4W	PRR 5059

JUAB COUNTY

	Location			
Map No.	Section	Township	Range	Data Source
U-400	11 mi E of Nephi			PRR 5217
U-401		12S	15W	PRR 5215
U-402	22 or 23	10S?	3W	PRR 5214
U-403	?	12S	2W	PRR 5213
U-404	16?	11S	18W	PRR 5225
U-405	?	14S	11W	PRR 5224
U-406	?	14S	11W	PRR 5223
U-407	27	11S	5W	PRR 5222
U-408	27	11S	5W	PRR 5221
U-409	27	11S	5W	PRR 5220
U-410	35	12S	12W	PRR 5231
U-411	7	13S	15W	GJBX 36/78
U-412	?	12S	7W	PRR 5219
U-413	?	12S	12W	PRR 5218
U-414		14S	2W	PRR 5227
U-415	?	12S	12W	PRR 5241
U-417		11S	14W	PRR 5239
U-418	10	13S	12W	PRR 5249
U-419		12S	12W	PRR 5248
U-420	34	12S	12W	PRR 5247
U-421		12S	12W	PRR 5246
U-422		12S	12W	PRR 5245
U-423	7	13S	15W	GJBX 36/78
U-424	10,15,16	13S	11W	PRR 5257
U-425		12S	12W	PRR 5256

JUAB COUNTY

	Location			
Map No.	Section	Township	Range	Data Source
U-426	2	12S	12W	PRR 5255
U-427		13S	12W	PRR 5254
U-428		12S	12W	PRR 5253
U-429	10	13S	12W	PRR 5252
U-430		12S	12W	PRR 5251
U-431		12S	12W	PRR 5242
U-432		12S	12W	PRR 5243
U-433		16S	1W	PRR 5226
U-434		13S	12W	B
U-435	11	13S	12W	B
U-436	36	12S	12W	B
U-437	21	12S	12W	B
U-438	28	12S	12W	B
U-439	27	12S	12W	B
U-440	36	11S	18W	B

MILLARD COUNTY

	Location			
Map No.	Section	Township	Range	Data Source
U-200	2	18S	11W	PRR 5311
U-201	31	18S	11W	PRR 5310
U-204	10	23S	14W	PRR 5308
U-205	?	18S	11W	PRR 5309
U-206	7	23S	14W	PRR 5307
U-207	17,20	21S	14W	PRR 5306
U-208	10	23S	14W	PRR 5318
U-210		16S	16W	PRR 5317
U-211	?	15S	11W	PRR 5316
U-212	?	15S	11W	PRR 5315
U-213	?	15S	11W	PRR 5314
U-214		21S	4W	PRR 5312
U-215		18S?	11W	PRR 5313

TOOELE COUNTY

	Location			
Map No.	Section	Township	Range	Data Source
U-100	?	10S	6W	PRR 5502
U-102		10S	6&7W	PRR 5516
U-104	17?	10S	6W	PRR 5500
U-105	7	10S	6W	PRR 5499
U-106		2,3N	8&9W	PRR 4984
U-107		2,4N	17&18W	PRR 5506
U-108	12?	10S	7W	PRR 5515
U-109		10S?	7W?	PRR 5503
U-110	7	10S	6W	B
U-111	28	10S	6W	B
U-112	28	12S	7W	B

WASHINGTON (Map C-7)

FERRY COUNTY

Map No.	Location			Data Source
	Section	Township	Range	
W-500	23	38N	34E	PRR 5633
W-501	22	39N	36E	PRR 5632
W-502	25	39N	35E	PRR 5631
	30	39N	36E	PRR 5631
W-503	30	37N	37E	PRR 5630
W-504	12	37N	36E	PRR 5629
	7	37N	37E	PRR 5629
W-505	1,12	35N	35E	PRR 5641
W-506	7	36N	37E	PRR 5640
W-507	25	37N	36E	PRR 5639
W-508	26	37N	36E	PRR 5638
W-509	36	37N	36E	PRR 5637
W-510	25	37N	36E	PRR 5636
W-511	11,12	35N	35E	PRR 5649
W-512	20	35N	36E	PRR 5648
W-513	31	37N	36E	PRR 5647
W-514	3	35N	35E	PRR 5646
W-516	3	36N	37E	PRR 5644
W-517	30,31	37N	37E	PRR 5634
W-518	34	36N	35E	PRR 5642
W-519	30	36N	36E	PRR 5645
W-520	5	36N	34E	PRR 5643
W-521	6	37N	37E	PRR 5657
W-522	27	39N	34E	PRR 5656
W-523	26	38N	34W	PRR 5655
W-524	23	38N	34E	PRR 5653
W-525	23	38N	34E	PRR 5652
W-526	14	38N	34E	PRR 5664
W-527	15	38N	34E	PRR 5663
W-528	20	36N	37E	PRR 5662
W-529	23	38N	34E	PRR 5661
W-530	23	33N	34E	PRR 5660
W-531		29N	33E	PRR 5673
W-532	21	36N	37E	PRR 5668
W-533	21	35N	37E	PRR 5674
W-535	1	38N	36E	PRR 5650
W-536	23	38N	34E	PRR 5659
W-537	21	36N	37E	PRR 5668
W-538	28	37N	37E	PRR 5666
W-539	36	37N	36E	PRR 5637
W-540	15	31N	32N	B
W-541	5	36N	34E	B

LINCOLN COUNTY

Map No.	Location Section	Township	Range	Data Source
W-200	34	27N	37E	PRR 5684
W-201	32	28N	37E	PRR 5682
W-202	32	28N	37E	PRR 5681
W-203	7,8,17,18	27N	37E	PRR 5680

OKANOGAN

Map No.	Location Section	Township	Range	Data Source
W-300	10	32N	27E	PRR 5686
W-301	26	35N	31E	PRR 5685
W-302	14	34N	26E	PRR 5694
W-303	34	31N	29E	PRR 5693
W-304	23	40N	26E	PRR 5704
W-305	33	36N	31E	PRR 5703
W-306	27	36N	31E	PRR 5702
W-307	9	40N	26E	PRR 5701
W-308	34	36N	31E	PRR 5692
W-309	27,28	36N	25E	PRR 5700
W-310	11,12,10,13,14,15,24	37N	26E	PRR 5709
W-311	25	35N	31E	M
W-312	15	36N	29E	M
W-313	24	31N	29E	B
W-314	10	32N	25E	B
W-315	14	34N	25E	B
W-316	14	38N	24E	B
W-317	26	39N	29E	B
W-318	5	40N	29E	B
W-319	23	40N	25E	B
W-320	3,4	29N	31E	PRR 5651

PEND OREILLE

Map No.	Location Section	Township	Range	Data Source
W-400	24	36N	42E	PRR 5715
W-401	22	35N	45E	PRR 5714
W-402	13	36N	45E	PRR 5713
W-403	39?	36N	43E	PRR 5712
W-404	13	35N	45E	PRR 5710
W-405	12	32N	42E	PRR 5722
W-406	6	34N	44E	PRR 5720
W-407	24	31N	44E	PRR 5719
W-408	13,18	35N	45,46E	PRR 5718
W-409	13,18,19,24	35N	45,46E	PRR 5729
W-410	17	35N	43E	PRR 5728
W-411	6	35N	45E	PRR 5727
W-412	32	30N	45E	PRR 5726
W-413	23	36N	43E	PRR 5725
W-414	32	30N	45E	PRR 5733
W-415	31,32	34N	45E	PRR 5732

PEND OREILLE

Map No.	Location Section	Township	Range	Data Source
W-416	29	39N	43E	PRR 5739
W-417	15,22	39N	43E	PRR 5738
W-418	32	30N	45E	PRR 5733
W-419	16,21	39N	43E	PRR 5721
W-420	6	34N	44E	M
W-421	10	32N	44E	M
W-422	6	33N	45E	M
W-423	36?	33N	42E	M
W-424	32	39N	43E	M
W-425	10	32N	42E	B
W-426	32	34N	44E	B
W-427	5?	35N	43E	B
W-428	32	36N	43E	B
W-429	26	38N	45E	B
W-430	18	38N	43E	B
W-431	16	39N	43E	B

SPOKANE

Map No.	Location Section	Township	Range	Data Source
W-150	7	28N	45E	PRR 5760
W-151	1	28N	44E	PRR 5759
W-153	32,33	24N	42E	M
W-154	1	29N	44E	B

STEVENS COUNTY

Map No.	Location Section	Township	Range	Data Source
W-100	29	34N	39E	PRR 5789
W-101	12, 1	29N	37E	PRR 5788
W-102	3	28N	40E	PRR 5787
W-103	1	29N	40E	PRR 5786
W-104	27	34N	40E	PRR 5741
W-105	11	27N	37E	PRR 5792
W-106	14	34N	39E	PRR 5793
W-107	21	29N	38E	PRR 5794
W-108	23	40N	36E	PRR 5795
W-109	26	40N	36E	PRR 5796
W-110	9	38N	39E	PRR 5797
W-111	14	27N	37E	PRR 5803
W-112	1,12	28N	37E	PRR 5805
	6	28N	38E	PRR 5804
W-113	15	28N	37E	PRR 5805
W-114	13	27N	37E	PRR 5801
W-115	12	34N	39E	PRR 5791
W-116	35	28N	37E	PRR 5790
W-117	14	29N	37E	PRR 5798

STEVENS COUNTY (cont.)

Map No.	Location Section	Township	Range	Data Source
W-118	28	34N	40E	PRR 5799
W-119	28	34N	40E	PRR 5813
W-120	13	28N	37E	PRR 5818
W-121	12	34N	39E	PRR 5817
W-122	29	31N	42E	PRR 5816
W-123	6	30N	38E	PRR 5815
W-124	23	29N	38E	M
W-125	16	28N	38E	M
W-126	10	29N	37E	M
W-127	16?	34N	38E	B
W-128	33	34N	42E	B
W-129	33	34N	42E	B
W-130	6	38N	37E	B
W-131	1?	38N?	37E?	B

APPENDIX D

GEOLOGY, URANIUM FAVORABILITY, URANIUM OCCURRENCES AND TECTONIC MAPS OF INDIVIDUAL CORDILLERAN METAMORPHIC CORE COMPLEXES

By

Stephen J. Reynolds, Steven H. Lingrey, Charles F. Kluth,

Diane C. Ferris and Stanley B. Keith

Introduction

The appendix contains individual reports on the geology, uranium favorability, and uranium occurrences of each Cordilleran metamorphic core complex. It is accompanied by tectonic maps of each complex or related group of complexes at a scale of 1:250,000. The location of known uranium occurrences are also plotted on each map.

The geological section of each report summarizes the location, pertinent geological literature, general geology, major rock units as depicted on the corresponding tectonic maps and geological evolution of one or several related complexes. The geologic section for each complex is individually authored by Reynolds, Lingrey, or Kluth for different complexes. The sections on uranium favorability of each complex are written by Reynolds. These are necessarily brief and preliminary in nature because there is much additional work to be done before the uranium favorability of each complex is known with more certainty. A list of the geology of known uranium occurrences compiled by Ferris follows the uranium favorability section of each complex. The locations of the occurrences are listed in Appendix C and plotted on the appropriate tectonic map. Additional detail on the geology of each occurrence can be found in the original reference cited in Appendix C.

The tectonic maps were compiled from available information by Lingrey, Kluth, Reynolds, and Keith. The sources of data are included in the bibliography contained in Appendix A. In some cases, the geologic maps are based on unpublished geological mapping, geochronology and geological reconnaissance of the present authors. These tectonic maps, in conjunction with the corresponding reports, will faciliate more detailed evaluation of the uranium potential of each complex.

OKANOGAN CRYSTALLINE COMPLEX

GEOLOGY

By

Stephen J. Reynolds

Introduction

The Okanogan crystalline complex is located in north-central Washington between the Okanogan River on the west and the Republic graben on the east Plutonic and metamorphic rocks along the southern margin of the complex are overlain by basalts of the Columbia River Group. The north part of the complex merges with the Omineca crystalline belt of Canada. Waters and Krauskopf (1941) interpreted the geology of the Okanogan complex in terms of a protoclastic margin that surrounded an undeformed 'Colville batholith.' Snook (1965) studied the petrology of metamorphic, mylonitic and plutonic rocks of the complex and recognized the presence of metasedimentary units. Fox and others (1976, 1977) reinterpreted the geology of the area as a gneiss dome and determined radiometric ages of many of the major rock units. Cheney (1980) briefly discussed the geology of the region in his study of the adjacent Kettle complex.

General Geology

The Okanogan complex is a domal mass of crystalline rocks that rests within a collage of 'oceanic' terranes. The crystalline core of the complex contains a central area of amphibolitic, alaskitic and calcareous metamorphic rocks (Tonasket Gneiss), surrounded on three sides by a sheath of variably foliated granitoid rocks. U-Pb ages on the gneiss (Fox and others, 1976) are difficult to interpret, but may indicate a Mesozoic protolith. K-Ar hornblende ages require metamorphic gradients persisting into Eocene times. K-Ar biotite and fission-track ages firmly document that final cooling of the crystalline core was also an Eocene phenomenon (Fox and others, 1976). Plutonic rocks that surround the gneiss also yield Eocene cooling ages; at least one pluton has an Eocene emplacement age. Foliation in the plutonic rocks becomes less pronounced up structural section to the south, east and north until undeformed plutonic textures predominate. In contrast, as rocks of the crystalline core are traced westward toward the Okanogan River valley, evidence of brittle deformation becomes more evident. The author has observed highly shattered rocks along this margin that strongly resemble the chloritic breccias of other core complexes. Above this faulted western margin (or dislocation zone) of the complex are less metamorphosed rocks that include Permian and Triassic sedimentary and volcanic rocks, as well as abundant Mesozoic plutonic rocks. The general restriction of Eocene volcanic and sedimentary rocks to the vicinity of the Okanogan River valley suggests that they are allochthonous above the dislocation surface. If so, the rocks may owe their present eastward dip and preservation from erosion to antithetic rotation that accompanied their westward transport on the dislocation surface. South of the complex lie the voluminous basalts of the Miocene Columbia River Group which post-date all major activity in the Okanogan complex.

Rock Units

Crystalline Core

m - Undifferentiated metamorphic rocks. This unit includes amphibolitic, alaskitic and calcareous metamorphic rocks of the Tonasket Gneiss. Ages of protolith and metamorphism are uncertain.

gg - Granitic gneiss. Rocks indicated by this term are gneissic rocks of granitic composition which probably represent deformed plutonic rocks. They are of unknown age.

KTg or Tg - Granitic rocks. The lower case letters following the small 'g' depict the age or possible range in age. Lowercase letters that follow the 'g' indicate whether the rock is muscovite-bearing (m), hornblende-bearing (h), or foliated (f).

Cover

uP - Upper Paleozoic sedimentary and volcanic rocks. Sedimentary rocks are mostly graywacke, limestone, argillite and chert whereas volcanic rocks are mafic in composition. Both types of rocks are locally metamorphosed and highly deformed. Triassic rocks are locally included in this unit.

Jg or JKg - Granitic rocks, ranging in age from Jurassic to Cretaceous.

Ks - Cretaceous sedimentary rocks. These consist of conglomerate and sandstone deposited under continental or shallow marine conditions.

Tv - Tertiary volcanic rocks. These are Eocene in age and mostly intermediate to felsic in composition.

Ts - Tertiary sedimentary rocks. This unit consists of continental sandstone and conglomerate of probable late Eocene to early Oligocene age.

Post-Middle Miocene Units

Tb - Tertiary basalts of the Columbia River Group.

TQs - Late Tertiary - Quaternary surficial deposits. These include relatively unconsolidated sediments deposited by alluvial, colluvial, eolean, and glacial processes.

Geological Evolution

The following discussion of the geological evolution of the Okanogan complex primary reflects the beliefs of the present author. Other hypotheses are contained in publications by Waters and Krauskopf (1941), Snook (1965), Fox and others (1976, 1977), and Cheney (1980).

The Okanogan complex lies within a region which contains no documented Precambrian basement. The nearest exposures of typical North American Precambrian basement are those in the Selkirk complex of northeastern Washington. Precambrian rocks of northern Cascade Mountains west of the Okanogan complex are of uncertain provenence. Metamorphic rocks that are exposed peripheral to the complex (such as the Tenas Mary Creek sequence) may have Paleozoic and Mesozoic rather than Precambrian ancestries. The early Paleozoic history of the region is uncertain because the Okanogan complex lies outboard of the stratigraphically determined Paleozoic edge of North America. Upper Paleozoic rocks and lower Mesozoic rocks on both sides of the complex have oceanic affinities. This oceanic regime was converted into one which was quasi-continental during the middle of the Mesozoic. At this time, the region became part of a magmatic arc which shed detritus westward into the Methow fore-arc basin. Some granitic rocks in the Okanogan complex may be remnants of this Jurassic arc.

Plutonism and metamorphism in the complex had probably commenced by Cretaceous or earliest Tertiary time, however, much metamorphism and some of the plutonism must be Eocene. Mylonitization and formation of the chloritic breccia and accompanying dislocation surface are probably also Eocene in age, although there are other interpretations (Fox and others, 1976, 1977). Tertiary and older rocks that are presently exposed west of the complex were probably tilted during westward transport on the dislocation surface. This may have been closely followed by final arching of metamorphic and mylonitic rocks in the crystalline core of the complex. Subsequent to all major activity in the complex, voluminous basalts of the Columbia River Group were erupted south of the complex in middle Miocene time. The landscape of the Okanogan complex and vicinity was dramatically modified in the Quaternary when fluvial, glacial and periglacial processes were dominant.

URANIUM FAVORABILITY

There are approximately ten uranium occurrences within or adjacent to the Okanogan complex. The occurrences are characteristically associated with granite or pegmatite. Some of these occurrences contain quartz veins of possible hydrothermal origin, but other occurrences are found in unaltered pegmatite or weathered granite. The Okanogan complex does not share the the adjacent Kettle complex's propensity for uranium occurrences. A high proportion of metamorphic rocks in the complex are mafic in composition; these were probably formed via metamorphism of mafic igneous rocks. As such, they are poor sources of uranium. The complex is probably not underlain by Precambrian basement but instead evolved within a collage of "oceanic" terranes. This attribute makes the complex very unfavorable for many types of uranium occurrences (i.e. unconformity-related deposits). Plutonic rocks in the complex have below average uranium contents that typically range from less than 1 ppm to slightly greater the 4 ppm (Marjaniemi and Basler, 1972; Munroe and others, 1975; Castor and others, 1977). These low uranium contents verify the complex's low uranium favorability. In addition, Marjaniemi and Robins (1976) concluded that Tertiary sedimentary rocks along the Okanogan Valley have low uranium favorability.

URANIUM OCCURRENCES

W-300 - The host rock is a high feldspar pegmatite lying in contact with a vein of milky quartz.

W-301 - Radioactive occurrence is in a quartz vein in metasedimentary host rock.

W-302 - Anomalous radioactivity occurs in a sheared zone in granite. A black mud within the shear zone appears to be radioactive however when the mud is moved away from seepage water in the zone its count drops.

W-304 - Radioactivity occurs in a fine grained silicified fault gouge in granite.

W-305 - Radioactivity occurs in a somewhat decomposed granite with serpentine and clay developed on the fracture.

W-306 - Radioactivity occurs in a granite and granite pegmatite. No vein system was noted.

W-307 - Radioactivity occurs in the contact between Similkameen batholith granite on the west and Paleozoic gneiss on the east.

W-308 - Radioactivity occurs in a scattered zone in granite near a contact with a basic dike.

W-309 - Radioactivity occurs in mica schists intruded by occasional pegmatites.

W-310 - Radioactivity occurs in a Paleozoic gneiss - schist - phyllite host rock dipping east 50°-60°.

W-311 - Radioactivity occurs in a pegmatite. Host rock assumed to be plutonic.

W-312 - Radioactivity occurs in a pegmatite. Host rock assumed to be plutonic.

W-314 - Radioactivity occurs in stringers in pegmatites associated with a quartz vein.

W-315 - Available information is insufficient to determine host rock.

W-316 - Available information is insufficient to determine host rock.

W-317 - Available information is insufficient to determine host rock.

W-318 - Available information is insufficient to determine host rock.

W-319 - Radioactivity occurs in fault gouge in a granitic host rock.

KETTLE COMPLEX

GEOLOGY

By

Stephen J. Reynolds

Introduction

The Kettle complex is located in the north-trending Kettle River Range of northeastern Washington. The complex is bounded on the west by marginal faults of the NNE-trending Republic graben (or Sandpoil syncline). The fault-bounded eastern margin of the complex closely follows segments of the Columbia and Kettle Rivers. Crystalline rocks of the complex merge northward into the Grand Forks terrane of British Columbia. Rocks exposed south of the Kettle complex consist of an assortment of eugeosynclinal upper Paleozoic (?) rocks, Cretaceous granites, and Middle Miocene basalts of the Columbia River Group.

The first map of the entire Kettle complex was that published by Cheney (1980). Earlier studies were either of a reconnaissance nature (Parde, 1918) or were concerned with only part of the complex (Bowman, 1950; Campbell, 1938; Lyons, 1967; Muessig, 1967; Parker and Calkins, 1964; Pearson, 1977). There is clearly much detailed geologic mapping and geochronology to be done before the geology of the complex is known with more certainty.

General Geology

The Kettle complex is a northerly elongated dome of metamorphic and granitic rocks (Cheney, 1980). The crystalline core of the complex has a mappable stratigraphy which is dominated by biotitic schist and gneiss, granitic and pegmatitic gneiss, quartzite, amphibolite, and marble. Cheney has correlated these rocks with the Tenas Mary Creek sequence described by Parker and Calkins (1964) in an area west of the Kettle complex. A large proportion of the lithologies represent metasediments, but at least two large granitic gneiss units are probably deformed granitic sills. Foliation in both types of rocks is gently inclined and locally contains a pervasive east-trending lineation. Mylonitic textures are conspicuous in many areas of the complex.

Amphibolite and granitic gneiss along the eastern side of the complex are structurally overlain by quartzite. In some areas, the quartzite is converted into an ultra-mylonite which shares the same lineation as the underlying metamorphic rocks. This quartzite, questionably correlated to the Cambrian Gypsy Quartzite of northeastern Washington by Cheney (1980), is part of the metamorphic basement of the complex. The eastern margin of the complex is a low-angle dislocation surface, above which lie faulted Paleozoic (?) and Eocene rocks. Rocks below the dislocation surface strongly resemble the chloritic breccias of other complexes. The Eocene sedimentary and volcanic rocks have westerly dips, as if tilted by antithetic rotation that accompanied their eastward displacement above the dislocation surface.

Along its western extent the crystalline core of the complex merges with granitic plutons of probably Cretaceous or Eocene age. The granitic rocks are cut by normal faults that bound the Eocene Republic graben. The synformal aspect of the graben may be related to late arching of the Kettle dome.

There is very little conclusive geochronology on rocks of the Kettle complex. Precambrian ages are inferred for rocks of the complex (Cheney, 1980) based on model ages of Rb-Sr whole-rock analyses (R.L. Armstrong, 1979, written communication). However, the granitic gneisses sampled might just as easily be Mesozoic or Cenozoic intrusives that had relatively high (but not unreasonable) initial $^{87}Sr/^{86}Sr$ ratios. Eocene cooling or plutonism in the complex is indicated by K-ar ages discussed by Pearson and Obradovich (1977).

Rock Units

Crystalline Core

m - Undifferentiated metamorphic rocks of uncertain age. These include probably metasedimentary units of the Tenas Mary Creed sequence of Cheney (1980). Common lithologies are biotitic gneiss and schist, quartzite, amphibolite, and marble. Abundant pegmatites are locally interlayered with these rock types.

gg - Granitic gneiss of uncertain age. This unit includes granitic gneiss, pegmatite and slightly foliated granite.

JTgh - Jurassic (?) to Tertiary (?) foliated granitic rocks. These occur as discrete plutons of granite and granodiorite.

Tgh - Tertiary hornblende-bearing granite.

Cover

lP - Lower Paleozoic rocks. This unit includes carbonate and clastic rocks which are generally unmetamorphosed.

uP - Upper Paleozoic rocks. These are a poorly understood assemblage of immature detrital rocks, mafic volcanic units, and carbonate lithologies. Their age is uncertain, but probably upper Paleozoic.

Jvs - Jurassic volcanic and sedimentary rocks. These are similar to typical lithologies of the Rossland Formation.

Ks - Cretaceous (?) sedimentary rocks. This unit includes clastic sedimentary rocks of possible Cretaceous age.

Tv - Tertiary volcanic rocks. These are interbedded lava flows and ash-flow tuffs of Eocene age. Sedimentary rocks are locally present in rocks mapped as this unit.

Ts - Tertiary sedimentary rocks. This unit contains continental sedimentary rocks such as sandstone and conglomerate.

Post-Middle Miocene Units

TQs - Tertiary-Quaternary surficial deposits. These include relatively unconsolidated sediments deposited by alluvial, glacial, colluvial, lacustrine, and eolian processes.

Geological Evolution

The geological history of the Kettle complex and its environs is not well known. It is uncertain whether the area is underlain by Precambrian basement; none has been documented in the area. During the late Precambrian and Paleozoic, northeastern Washington, as part of the Cordilleran Miogeocline,was the site of carbonate and clastic deposition. The Kettle complex is positioned west of or very near to the stratigraphically inferred edge of the continental shelf. Accordingly, Paleozoic rocks of eugeosynclinal aspect that occur south of the complex may represent continental slope or abyssal deposits. It is entirely possible that the metamorphic lithologies of the Tenas Mary Creek sequence are derived from this assemblage of upper Paleozoic (?) rocks. Upper Paleozoic (?) or lower Mesozoic rocks exposed in the Republic graben west of the Kettle complex have some 'oceanic' aspects; therefore, the Kettle complex may have been within an 'oceanic' area during the late Paleozoic and early Mesozoic. In the middle Mesozoic, the area near the Kettle complex was experiencing plutonism and deformation. The Cretaceous was characterized by similar events. Metamorphism in the crystalline core of the Kettle complex may have been initiated in the Cretaceous but probably continued into the Tertiary. Plutonism, volcanism, sedimentation and possibly mylonitization also occurred in the Tertiary (Eocene). Dislocation along the eastern edge of the complex is almost certainly an Eocene event and development of the synclinal form of the Republic graben probably accompanied Eocene (?) arching of the crystalline core of the Kettle complex. In the middle of the Miocene, voluminous basalts were erupted south of the Kettle complex in the Columbia Plateau. Glacial, alluvial, and other surficial processes are responsible for the present landscape of the region.

URANIUM FAVORABILITY

There are more uranium occurrences in the crystalline core of the Kettle complex than in any other Cordilleran metamorphic core complex. An examination of the uranium occurrence maps provided with this report (Appendix C) indicates that the Kettle complex exhibits a density of uranium occurrences rivaling that of any other area within the Cordillera. A majority of occurrences within the Kettle complex are associated with uraniferous pegmatites. Others may owe their origin to metamorphic and mylonitic processes. The complex is fertile ground for uranium exploration and for research concerning the behavior of uranium during metamorphism and mylonitization. Locally high uranium contents of pegmatitic and metamorphic rocks make the complex ideal for both pursuits. A potentially very favorable area is the chloritic dislocation zone along the eastern flank of the complex. This zone has been interpreted as a high-angle fault (Bowman, 1950), but it more likely dips gently to the east. Deep drilling should be undertaken to evaluate whether uranium has been leached from the uraniferous core rocks and redeposited at depth along the dislocation zone (Cheney, 1980). The uranium favorability of the Kettle complex is probably the highest of all the Cordilleran metamorphic core complexes.

URANIUM OCCURRENCES

W-108 - Uranium mineralization occurs along the contact between a quartz vein and metamorphic rocks.

W-109 - Uranium occurs in fractures and foliation planes of a biotite schist and quartzite.

W-130 - Radioactivity occurs in pegmatite near gneiss and granite.

W-500 - Uranium minerals occur in a small quartz-rich pegmatite in gneiss.

W-501 - Radioactivity occurs in granite gneiss, normal granite and a hornblende-biotite schist intruded by pegmatites.

W-502 - Uranium(?) associated with biotite-rich pegmatite is found in a complex sequence of biotite gneiss, schist and quartzite.

W-503 - Radioactivity is associated with pegmatites that are interlayered with biotite schist and quartzite.

W-504 - Radioactivity occurs in a medium-grained muscovite pegmatite.

W-505 - Radioactivity occurs in a pegmatite near schist and gneiss.

W-506 - Radioactivity occurs in outcrops of granite, pegmatite and gneiss.

W-507 - Uranium is present along fractures in a pegmatite that is interlayered with metamorphic rocks.

W-508 - Uranium is present along a contact between gneiss and a pegmatite.

W-509 - Uranium mineralization is found as fracture coatings in massive pegmatites of light grey feldspar and quartz containing some biotite stringers small garnets are abundant.

W-510 - Uranium occurs along a pegmatite gneiss contact.

W-511 - Radioactive minerals occur in a garnetiferous pegmatite of graphic granite.

W-512 - Radioactivity occurs in a pegmatite that contains biotite and garnet.

W-513 - Radioactivity occurs in pegmatites interlayered with gneiss.

W-514 - Radioactivity occurs in biotite of a vein pegmatite in granite gneiss.

W-516 - Radioactivity occurs in a pegmatite that intrudes gneiss.

W-517 - Radioactivity occurs in a pegmatite intruding gneiss.

W-518 - Radioactivity is present in a biotite-muscovite pegmatite.

W-519 - Radioactivity occurs in a pegmatitic vein that contains muscovite.

W-520 - Radioactivity occurs in bands of schist and gneiss that are intruded by brecciated pegmatites.

W-521 - Radioactivity is found in a pegmatite that is fractured.

W-522 - Host rocks of radioactivity are pegmatite and gneiss.

W-523 - Radioactivity occurs in fractures in a pegmatite.

W-524 - Radioactivity occurs in granite and granite pegmatite.

W-525 - Radioactivity occurs in a fractured pegmatite.

W-526 - Radioactivity occurs in a granitic pegmatite. Biotite gneiss and massive quartz are also present.

W-527 - Radioactivity occurs in pegmatite stringers in biotite gneiss host rock.

W-528 - Radioactivity occurs in pegmatite stringers in a fine grained granitic host rock.

W-529 - Radioactivity occurs in a pegmatite that is bordered on two sides by gneiss.

W-530 - Radioactivity occurs in pegmatite "ledges" in gneiss.

W-532 - Radioactivity occurs in a pegmatite intruding gneiss.

W-533 - Radioactivity occurs in pegmatites in biotite - hornblende gneiss.

W-535 - Radioactivity is associated with a set of vertical fractures in pegmatite interlayered with gneiss.

W-536 - Radioactivity occurs in stringers of quartzite and pegmatite in banded gneiss.

W-537 - Radioactivity occurs in pegmatite in schists and gneiss.

W-538 - Radioactivity occurs in biotite-chlorite schist and quartzite of Paleozoic(?) age.

W-539 - Radioactivity is in the massive pegmatites of the eastern border of the Colville batholith.

W-541 - This occurrence is possibly the Mayo Claim of Minobras (1979); if so, uranium minerals are associated with epidote in marble intruded by granite.

SELKIRK CRYSTALLINE COMPLEX

GEOLOGY

By

Stephen J. Reynolds

Introduction

The Selkirk Mountains are located in northern Idaho and northeastern Washington at elevations above sea level that range from less than 2000 feet along the mountain fronts to over 7000 feet in the highest peaks of the Selkirk crest. Major drainages such as the Pend Oreille, Kootenay, Spokane, and Priest Rivers share broad valleys with several major lakes (Pend Oreille, Coeur d'Alene, and Priest).

The geology of various parts of the region has been studied by numerous workers (Calkins, 1909; Kirkham and Ellis, 1926; Anderson, 1940; Barnes, 1965; Nevin, 1966; Clark, 1967, 1973; Savage, 1967; Harrison and others, 1972; Miller and Engles, 1975). Key quadrangles have been mapped by Miller (1974), Miller and Clark (1975), Griggs (1973), Weis (1968), Weissenborn and Weis (1976), and Harrison and co-workers (see Appendix A). The primary geochronologic studies of the area are by Miller and Engels (1975), Miller and Clark (1975), and Yates and Engels (1965).

During geological reconnaissance of the area in 1977, the author and William A. Rehrig recognized that many aspects of the geology of the region bore strong resemblance to metamorphic core complexes of Arizona. The following discussion is based primarily on the results of this unpublished fieldwork and on a synthesis of all previously published works. The geology of the northern Idaho northeastern Washington region has not been previously integrated with the concept of metamorphic core complexes, although S.B. Castor and F.K. Miller (1980, personal communication) have also observed the similarity of this area to metamorphic core complexes elsewhere. The area is also referred to as the Priest River crystalline complex.

General Geology

The Selkirk crystalline complex is an assortment of plutonic and metamorphic rocks that constitute most of the Selkirk Mountains of northern Idaho and northeastern Washington. The complex as presently known is bounded on the east by the Purcell Trench. The trench separates foliated plutonic and high-grade metamorphic rocks of the complex west of the trench from less metamorphosed Belt Supergroup rocks that lie east of the trench. The main mass of the complex extends from the area of metamorphic rocks exposed west of Coeur d'Alene Lake through the Mount Spokane - Spirit Lake mountain massif and northward along the Selkirk crest to near the Canadian border. Near Mount Spokane, the complex bifurcates with a prong of plutonic and high-grade metamorphic rocks that lies south and west of the western Newport fault (Miller, 1972). The metamorphic and plutonic rocks of the complex in the areas outlined above share an important attribute: all yield Eocene cooling ages determined by either K-Ar (Miller and Engels, 1975) or Rb-Sr methods (Reynolds, Rehrig, and Armstrong, in preparation). In fact, the complex is neatly outlined by the figures of Miller and Engels (1975) which indicate areas of plutonic rocks that yield K-Ar cooling ages of less than 50 m.y.B.P. Unpublished Rb-Sr data document Eocene cooling for areas of metamorphic rocks as well.

The crystalline core of the complex is underlain by plutonic and high-grade metamorphic rocks. The metamorphic rocks include biotite-rich schist and gneiss (such as the Hauser Lake gneiss) quartzo-feldspathic gneiss, highly metamorphosed quartzite, and augen gneiss,(including the Laclede and Newman Lake gneisses). Published and unpublished geochronologic data indicate that some of these units have Precambrian ancestries. Plutonic rocks are abundant in the complex and crop out over extensive areas. Some of the oldest plutons are interlayered with the metamorphic rocks and are probably Precambrian. However, most of the granitic rocks in the complex are either Cretaceous or Eocene. As documented by Miller and Engels (1975), many of these granites contain muscovite and garnet. These muscovite granites are typically accompanied by extensive alaskitic, pegmatitic, and aplitic phases. This is beautifully displayed on the geologic map of the Mount Spokane Quadrangle by Weissenborn and Weis (1976). In this area, pegmatites and alaskites (including those which contain autunite mineralization) represent the upper parts of a large muscovite-granite pluton. The lower structural levels of this sill-like (?) granite are foliated, and are very reminiscent of the Santa Catalina Mountains of Arizona. The similarity in the overall plutonic-metamorphic "stratigraphy" between the two areas is striking! Throughout the remainder of the Selkirk complex, muscovite-granites are abundant and are commonly foliated. The largest area of relatively undeformed muscovite-granite underlies the Selkirk crest of Idaho. This area also contains hornblende-bearing granites near its southern end. Hornblende-bearing granites are more abundant to the west (i.e. the Eocene Silver Point Quartz Monzonite) and in the upper plate of the Newport fault or dislocation surface.

Plutonic and metamorphic rocks in the core of the complex are locally well foliated. In some cases this foliation is mylonitic and contains a conspicuous east- to northeast-trending lineation. The foliation in all rock units is usually gently dipping and defines several broad arches.

Perhaps the most spectacular feature of the Selkirk complex is the Newport Fault described by Miller (1972, 1974; see also Miller and Engels, 1975). The Newport fault is exposed in a 'U'-shaped trace that extends south along the Priest River; then westward and northward along the Pend Oreille River. The fault separates metamorphic and locally foliated plutonic rocks of the Selkirk complex from an upper plate of low-grade Belt Supergroup sedimentary rocks and associated diabasic sills, Cretaceous granites, and Eocene volcanic and sedimentary rocks. The footwall of the Newport fault contains a chloritic breccia that is identical to those exposed in other core complexes. The present U-shaped trace of the fault reflects a spoon-like geometry which is presumably the result of broad warping of an originally flat surface (Miller and Engels, 1975). Bedding in Belt Supergroup units in the upper plate is highly tilted, possibly due to antithetic rotation that accompanied movement on the Newport dislocation surface. The westerly dip of these rocks and overlying Eocene volcanics would suggest transport to the east. The Eocene Tiger Formation may represent clastic deposition in a basin formed during dislocation. The cross-sections of Miller (1974) are very suggestive of such a relationship.

The eastern boundary of the complex, the Purcell Trench, is more problematical. The trench is a mylonitic zone and structural-metamorphic discontinuity, but it generally lacks a well-developed chloritic breccia. Rocks west of the trench are of a much higher metamorphic grade than those east of it. In any event, the trench is clearly the eastern margin of the complex.

Rock Units

Crystalline Core

m - Undifferented metamorphic rocks. These are high-grade gneiss and schist of uncertain ancestry.

<u>msg</u> - Metasedimentary rocks. This unit includes metasedimentary rocks of uncertain age. They probably represent

Precambrian protoliths which were last metamorphosed in the Cretaceous or Eocene.

gg - Granitic gneiss. These rocks are generally coarse-grained augen gneiss derived from Precambrian plutonic rocks.

P€ym - Metamorphosed Precambrian Belt Supergroup rocks. These are metamorphosed clastic rocks with locally abundant metadiabase.

KTg - Cretaceous or Tertiary granitic rocks. The upper-case letters before the 'g' indicate the age or range in age of the granitic rocks. Lower-case letters placed after the 'g' indicate whether the granite is muscovite-bearing (m), hornblende-bearing (h), or foliated (f).

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P€y - Belt Supergroup sedimentary rocks. These rocks are mostly fine-grained clastic rocks with local carbonate units. They have been relatively unaffected by dynamothermal metamorphism.

P€w - Late Precambrian and Cambrian clastic rocks. THis unit includes post-Belt but pre-middle Cambrian clastic rocks and significant Late Precambrian volcanic rocks.

lP - Lower Paleozoic rocks. This unit includes Paleozoic carbonate and clastic sedimentary rocks, excluding the basal Cambrian quartzite which is included with the previous unit.

Ks - Cretaceous (?) sedimentary rocks. These are a poorly known series of clastic rocks of possible Cretaceous age. It includes the Sandpoint Conglomerate.

Tv - Tertiary volcanic rocks. This unit includes Eocene intermediate to felsic lava flows and ash-flow tuffs.

Ts - Tertiary sedimentary rocks. These are Eocene and possibly younger clastic rocks deposited under tectonically active, continental conditions.

Post-Eocene Units

Tb - Tertiary basalts of the Columbia River Group (middle Miocene)

TQs - Late Tertiary-Quaternary surficial deposits. This unit includes relatively unconsolidated sediments of alluvial, glacial, colluvial, lacustrine, and eolian origin.

Geological Evolution

The oldest rocks exposed in northern Idaho are in the St. Joe region east of the complex (Reid and others, 1973). These reveal an unresolved sequence of metamorphic and plutonic events which may be late Archean or early to middle Proterozoic. Some metamorphic and granitic rocks within the Selkirk complex may have been formed by these events. In the middle of the Proterozoic, tectonism was succeeded by deposition of Belt Supergroup rocks in a relatively stable environment. Intrusion of diabasic sills occurred at about this same time. In the late Precambrian, volcanism west of the Selkirk complex (the Windermere Group) may reflect initial rifting of the Cordilleran continental margin. Volcanism was followed by late Precambrian to Paleozoic deposition of carbonate and clastic strata in the Cordilleran miogeocline (continental shelf). The edge of the continent may have been just west of the comples, along the present Columbia River. During the Mesozoic, the region experienced plutonism and deformation as a continental margin. In the middle Cretaceous, numerous granitic plutons were emplaced outside of and probably within the Selkirk complex. Metamorphism in the complex may have been initiated at this time.

The most profound interval of tectonism in the region was in the Eocene when large parts of the area were blanketed by intermediate to felsic volcanic rocks and associated sediments. Granitic plutons, such as the Silver Point Quartz Monzonite (Miller, 1974), were emplaced within the crystalline core of the Selkirk complex. The core of the complex was still hot during this time and may have been the site of intense metamorphism. Mylonitization in the complex is also probably an Eocene phenomenon. It was followed by Eocene cooling of the crystalline core and formation of the Newport dislocation surface (and underlying chloritic breccia). Tilting of upper-plate Belt Supergroup and Eocene volcanic rocks may have accompanied listric-normal faulting and eastward tectonic transport. Arching of the initially flat dislocation surface produced its present spoon-shaped geometry. In mid-Miocene time, basalts were erupted over large areas of the Columbia Plateau. More recent glacial, alluvial, and colluvial processes helped shape the present landscape.

URANIUM FAVORABILITY

The Selkirk complex and its environs are characterized by a profusion of uranium occurrences. Occurrences are abundant in the crystalline core of the complex, along its margins,and in upper-plate rocks. Uranium occurrences in the crystalline core are generally located in plutonic rocks and can be classified into two types: 1) pegmatitic, or 2) authigenic (see Mathews, 1978a, b). Some pegmatites in the complex exhibit anomalously high radioactivity, but these are evidently not sufficiently uraniferous to constitute exploitable reserves. In contrast, authigenic occurrences in the complex have produced uranium (i.e. the Mount Spokane area). Authigenic occurrences contain secondary uranium minerals (such as autunite and/or meta-autunite) which fill and coat fractures in weathered but otherwise unaltered granitic rocks. The Daybreak mine of the Mount Spokane area is one of the best examples of this type of mineralization in the world. The complex is clearly favorable for this type of occurrence, both within its crystalline core and in upper-plate Cretaceous granites. Granitic rocks within the complex locally contain anomalous background radioactivity. The study by Castor and others (1977) is especially useful in determining favorable zones of uraniferous granites.

Uranium occurrences are also present within early Tertiary sedimentary rocks, specifically the Eocene Tiger Formation of the Pend Oreille Valley. The uranium favorability of these rocks as exposed on the surface is generally low (Marjaniemi and Robins 1975), however they may have potential for deposits at depth. Uranium leached from granites in the crystalline core of the complex or in upper-plate positions could migrate with meteoric fluids down the hydraulic gradient of the Newport fault (dislocation surface). Carbonaceous material in the Tiger Formation might then have precipitated uranium from the fluids. Results of deep drilling along the dislocation surface bounding the Pend Oreille Valley are needed to evaluate uranium favorability.

The Selkirk complex contains an abundance of uranium occurrences, some of which have produced significant amounts of uranium. Many granitic rocks in the complex have anomalously high uranium contents. All data clearly indicate that the complex has high favorability for additional uranium deposits. Dislocation zones that flank the complex should be explored by deep drilling.

URANIUM OCCURRENCES

I-150 - Anomalous radioactivity is found along the margin of a porphyritic granite.

I-151 - Radioactivity occurs in Belt Supergroup quartzite and metasedimentary rocks.

I-200 - Radioactivity occurs in Cretaceous(?) granites and pegmatites.

I-201 - Radioactivity occurs in a vertical fault in Belt Supergroup quartzite.

I-202 - Radioactivity occurs in a pegmatite sill(?) in biotite gneiss.

I-203 - Radioactivity occurs in a faulted, coarse-grained quartz-feldspar-mica gneiss.

I-204 - The host rock is a fractured, fresh granite however the radioactivity is not structurally controlled.

I-205 - Radioactivity occurs in a pegmatite that intrudes the Selkirk batholith.

I-206 - Radioactivity occurs in diorite.

I-207 - Radioactivity occurs in a diorite(?).

I-300 - Commercial quantities of thorium are found in quartz veins in diorite of the Purcell sills.

I-301 - Radioactivity occurs in a fault between Belt series and a diorite dike.

I-302 - The host rock consist of pegmatites, schists and granite. Anamolous radioactivity is confined to the lower pegmatites.

I-303 - Radioactivity occurs in the Purcell Sills which intrude the Belt Supergroup.

I-304 - Radioactivity occurs in a brecciated quartzite of the Belt Group series.

I-305 - Radioactivity occurs in a mineralized shear zone in granite.

I-306 - Anomalously radioactive count is obtained from a "pod in a pegmatite."

I-307 - Radioactivity occurs in a pegmatite intruding schists.

I-308 - Radioactivity occurs in a shear zone cutting granitic rocks.

I-309 - Radioactivity occurs in fractures in sulfide bearing granitic rock.

I-310 - Radioactivity occurs in a pegmatite intruding quartz monzonite.

I-311 - Occurrence is a "vein type" in an unknown or unstated host rock.

W-122 - Radioactivity occurs in pegmatite to aplite dikes in coarse grained rocks of the Loon Lake batholith.

W-128 - Radioactivity occurs in a pegmatite dike cutting metasediments.

W-129 - Radioactivity occurs in a pegmatite dike cutting metasediments.

W-131 - Radioactivity occurs in a pegmatite in gneiss.

W-150 - Radioactivity occurs in N70-80W striking shear zones cutting granite and pegmatites.

W-151 - Radioactivity occurs in a fault trending N65E cutting granites and pegmatites of the Loon Lake batholith.

W-153 - Radioactivity is found in pegmatites.

W-154 - Autunite occurs in a pegmatite.

W-400 - Radioactivity occurs in a fault trending N40W and dipping 65NE cutting altered granite.

W-401 - The host rock is a coarse-grained porphyritic granite. Radioactivity occurs in clay zones at the bottom of a zone of decomposition.

W-402 - Radioactivity occurs in tight slips in granite of the Kaniksu batholith.

W-403 - Radioactivity occurs in the hanging wall of a fault cutting quartz monzonite of the Kaniksu batholith.

W-404 - Radioactivity occurs in a deeply weathered quartz monzonite of the Kaniksu batholith.

W-405 - Radioactivity occurs in several pegmatite bodies in a relatively fresh medium-grained granite.

W-406 - Radioactive host rock is the Oligocene(?) arkosic conglomerate of the Tiger Formation.

W-407 - Radioactivity occurs in a quartz rich granite-pegmatite complex. No structural control is evident.

W-408 - Radioactivity occurs in a coarse grained porphyritic granite containing occasional pegmatite-aplite dikes.

W-409 - Radioactivity occurs in two highly altered iron stained granite zones.

W-410 - Radioactivity occurs in a medium-grained granite that contains two irregular pegmatite bodies that trend N-S and dip W.

W-411 - The host rock is a medium-grained granite. Autunite occurs in an iron stained fracture.

W-412 - Radioactivity occurs in a mass of coarse grained granite (or pegmatite) trending N30°W.

W-413 - A "slight count" is detectible in irregular pegmatite bodies in a medium to coarse grained granite.

W-414 - Radioactivity occurs in a medium-grained granite.

W-415 - The host rock is an altered granite.

W-418 - Disseminations of autunite occur in a granite.

W-420 - Radioactivity occurs in a clay conglomerate of the Oligocene(?) Tiger Formation

W-421 - Radioactivity occurs as disseminations in weathered granite.

W-422 - Radioactivity occurs in a sheared zone in granite.

W-423 - Autunite occurs in a pegmatite.

W-425 - Uranium occurs in a gneissic-granitic host rock.

W-426 - Radioactivity occurs in the arkosic conglomerate of the Oligocene(?) Tiger Formation.

W-427 - Radioactivity occurs in a pegmatite.

W-428 - Radioactivity occurs in a pegmatite.

BITTERROOT COMPLEX

GEOLOGY

By

Stephen J. Reynolds

The Bitterroot complex is located along the Idaho - Montana border south of Missoula, Montana. The striking feature of the complex is the Bitterroot front, a north-trending mylonitic zone which dominates the landscape of the Bitterroot Valley for a length of approximately 100 km. The mylonitic front is manifested physiographically as a conspicuously planar slope which forms the gently inclined western wall of the Bitterroot Valley.

Lindgren (1904) was the first to describe the Bitterroot front, eloquently and accurately delineating its essential features. The contribution of Lindgren (1904) and Ross' later (1952) paper have been followed by the more recent studies of Hyndman, Chase and collegues. Hyndman (1980) discusses the geology of the complex, and proposes a model involving gravitational denudation and subsequent isostatic adjustment (see also Hyndman and others, 1975). Chase (1973) studied the detailed petrology of plutonic, metamorphic, and mylonitic rocks that occur near and within the Bitterroot frontal zone. Armstrong (1974, 1975) discussed the geochronology of the Bitterroot lobe of the Idaho Batholith and concluded that the plutonic rocks were emplaced in the late Cretaceous and early Tertiary. These inferences have been verified by detailed geochronology (U-Pb, Rb-Sr, and fission-track ages) reported by Chase and others (1978).

General Geology

The Bitterroot front of Montana is the north-trending eastern margin of the Bitterroot lobe of the Idaho Batholith. It is a remarkable planar slope that forms the western wall of the Bitterroot Valley. This unusual topography mimics the attitude of foliation in the mylonitic rocks that comprise the frontal zone. As pointed out by Lindgren (1904), this foliation consistently dips to the east at approximately 20 - 30 degrees. Down structural section to the west, the mylonitic fabric gradually decreases in intensity until undeformed granite and granodiorite predominate. In the northern part of the frontal zone, mylonitic rocks have been derived from probable older Precambrian metamorphic rocks. In this area, mylonitic fabric also dies out down section to the west. Therefore, the structurally lowest levels of the Bitterroot complex are occupied by metamorphosed Precambrian rocks and undeformed late Cretaceous or early Tertiary granite and granodiortie of the Idaho batholith. Probable Eocene epizonal granites have intruded along the diffuse western margin of the complex (Greenwood and Morrison, 1973; Hyndman, 1980).

To the east, mylonitic rocks of the Bitterroot front are in fault contact with relatively unmetamorphosed carbonate rocks (Precambrian Wallace Formation?). Most previous workers have inferred that this fault is high-angle and related to formation of a graben that underlies the Bitterroot Valley. However, along much of the Bitterroot front there is an unmapped zone of chloritic breccia that is derived from underlying mylonitic granites. The three-dimensional distribution of chloritic breccia exposures indicates that the breccia zone has a gentle eastward dip that conforms to the orientation of the underlying mylonitic foliation. The chloritic breccia probably formed in the footwall of a dislocation surface which separated mylonitic core rocks from nonmylonitic upper-plate rocks. The upper plate rocks thus include the carbonate rocks exposed near Victor on the western side of the Valley as well as an unknown proportion of the metamorphic and granitic rocks that lie east of the Bitterroot Valley. The dislocation surface has been observed at the southern edge of the Bitterroot complex where it separates chloritic breccia (mostly derived from mylonitic Idaho batholith granodiorite) from an upper plate that contains an assortment of highly shattered Eocene volcanic rocks.

Geochronology of the crystalline core of the complex has been discussed by Chase and others (1978). They conclude that the main stage of batholithic emplacement in the complex was in the latest Cretaceous or earliest Tertiary. Fission-track, K-Ar, and Rb-Sr ages indicate that the crystalline core of the complex was hot, but cooling during the Eocene. Mylonitization must have postdated emplacement of the batholith but predated final cooling of the complex in the Eocene. It is possible that mylonitization, like movement on the dislocation surface, is Eocene.

Rock Units

Crystalline Core

P€m - Precambrian metamorphic rocks. These are a wide variety of metasedimentary and metaigneous rocks that have probable Precambrian protoliths. Quartzo-feldspathic gneiss, mica schist, augen gneiss, and amphibolite are among the common rock types.

P€sm - Metamorphosed Precambrian sedimentary rocks. This unit includes metamorphosed clastic and carbonate rocks which may be correlative to the Precambrian Belt Supergroup.

Kg - Cretaceous granite and granodiorite of the Idaho batholith. These rocks range from undeformed to strongly foliated and grade into the following unit (KTm).

KTm - Cretaceous or Tertiary mylonitic rocks of the Bitterroot frontal zone. The rocks exhibit a gently inclined foliation and easterly trending lineation. They have been derived from Cretaceous or Tertiary granitic rocks and several types of Precambrian metamorphic rocks.

Tg - Tertiary granitic rocks. These are generally epizonal, potassic granites that occur along the western edge of the complex.

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P€s - Precambrian sedimentary rocks. This unit includes variably metamorphosed clastic and carbonate rocks that may be correlative to the Belt Supergroup.

Kg - Cretaceous granitic rocks. These granites are mainly exposed east of the Bitterroot Valley.

Tv - Tertiary volcanic rocks. These rocks are probably Eocene in age and represent all gradations between volcanic and subvolcanic facies. They are mostly intermediate to felsic in composition.

Post-Middle Miocene Units

TQs - Late Tertiary-Quaternary surficial deposits. These are composed of relatively unconsolidated sediments deposited by alluvial, glacial and colluvial processes. This unit includes fairly extensive lateral moraines along the west side of the Bitterroot Valley.

Geological Evolution

In the Precambrian, the Bitterrot region underwent a series of depositional, plutonic, and metamorphic events. Anorthosites and associated rocks in the core of the complex are tentatively assigned to the Archean and may have been the basement upon which younger Belt-age sediments were deposited. During the late Precambrian and Paleozoic, the region experienced relative tectonic quiescence as carbonate and clastic rocks were deposited in a platform environment. In the late Mesozoic, the main phase of the Bitterroot lobe of the Idaho batholith was emplaced. Further to the east near the Boulder Batholith, intrusion and thrusting occurred, accompanied by syntectonic sedimentation and volcanism. The Idaho batholith was subsequently subjected to an episode of mylonitization, probably in the Eocene. Movement on the dislocation surface and formation of the accompanying chloritic breccia may have been initiated as mylonitization was waning. Final uplift, cooling and arching of the complex may have been in response to isostatic adjustments as suggested by Hyndman (1980). Later in the Tertiary, high-angle normal faulting probably formed the graben that underlies parts of the Bitterroot Valley. Glacial and alluvial processes have embellished the Bitterroot front, transforming it into one of the most spectacular metamorphic core complexes of the North American Cordillera.

URANIUM FAVORABILITY

There are no reported uranium occurrences in the crystalline core of the Bitterroot complex. Most of the complex is underlain by Cretaceous granitoid rocks of the Idaho Batholith which have low to moderate radioactivity and uranium contents (Marjaniemi and Basler, 1972; Swanberg and Blackwell, 1973). These rocks and their mylonitic derivatives would not be expected to host significant uranium mineralization. In contrast to the Cretaceous granitic rocks, the Eocene granites of the batholith are characterized by higher radioactivity and uranium contents (Swanberg and Blackwell, 1973; Bennett, 1980). Eocene granitic and/or volcanic rocks flank the Bitterroot complex on three sides (Hyndman, 1980). Some of these exhibit high radioactivity but it is unknown whether they are associated with any uranium mineralization. Lead and zinc mineral deposits are present in Belt Supergroup carbonate rocks that lie above the dislocation surface near Victor. It is doubtful that the base-metals are accompanied by uranium. All things considered, the Bitterroot complex has low favorability for significant uranium reserves. Wopat and others (1977) conclude that Tertiary sediments of the Bitterroot basin have poor favorability for uranium deposits.

URANIUM OCCURRENCES

M-101 - The host rock is a biotite gneiss injected by a biotite pegmatite. Radioactivity occurs along joint planes in the gneiss and in association with biotite mica books in the pegmatite zones.

M-106 - Autunite and a "radioactive green fluorescent mineral" 'coat' a pegmatite in a gneissic host rock.

M-108 - Autunite occurs as fracture coatings on dikes that cut veinlets in quartz monzonite of the Idaho batholith. A possible origin for the coatings has been suggested as being an overlying Eocene(?) rhyolite.

M-111 - Radioactivity occurs in an "intrusive."

PIONEER MOUNTAINS

GEOLOGY

By

Charles F. Kluth

Introduction

The Pioneer Mountains are located in south-central Idaho, north of the Snake River Plain. They are located within a region of northwest-striking overthrusts which imbricated the Paleozoic sedimentary rocks during the Cretaceous Sevier Orogeny. The major data sources on the area are maps and synthesis by Dover (1969), and Dover and others (1976).

General Geology

The Pioneer metamorphic core complex is composed of a pair of northwest-trending elongate domes in which is exposed a core of foliated and lineated, greenschist - to upper amphibolite - grade metamorphic rocks. The southeast side of the core is truncated by a Tertiary high-angle fault. Exposed Precambrian (?) gneisses locally exhibit their original Precambrian (?) metamorphic texture despite being overprinted by later events. Sedimentary rocks, mostly of early Paleozoic age are metamorphosed and occur along the southwest side of the core. A mid-Tertiary granitic rock has intruded the core and is variably deformed. The overlying, generally late Paleozoic rocks are unmetamorphosed but have been thrust northeastward into the region. These cover rocks also contain younger-on-older, low-angle faults and abundant high-angle faults. Neither the low-angle thrusts nor the low-angle normal faults cut the core zone (Dover, 1969).

Rock Units

Crystalline Core

P€m - Precambrian Wildhorse Canyon Migmatitic Gneiss Complex; this unit is made up of heterogeneous migmatites derived, for the most part, from sedimentary protoliths.

PZm - Paleozoic (including late Precambrian) sedimentary rocks which have been affected by a single, low pressure metamorphic event. This unit is approximately 2000 m thick and is represented in its lower part by the Hyndman Formation (possibly upper Precambrian), pelitic schists, quartzite and calc-silicates. The upper part of this unit is dolomitic marbles of the East Fork Formation (possible Paleozoic rocks). Low-angle thrusting post-dates this metamorphic event (Dover, 1969).

Tg - Pioneer Mountains Pluton. This unit is an intrusive sheet ranging from gneissose quartz diorite to massive porphyritic quartz monzonite that Dover infers was intruded between the gneisses and metasediments during the waning stages of the metamorphic event. The pluton is similar to the marginal facies of the Idaho Batholith.

Cover

Pz - Paleozoic sedimentary rocks. This unit is (mostly middle - and upper) Paleozoic typical of the section in central Idaho. They are dominantly clastics discontinuously shed eastward from the Antler orogenic belt.

Tcv - Tertiary Challis Volcanics. This unit is generally intermediate to silicic tuffs and breccias of Eocene age.

Tg - Tertiary granitic rocks. This unit is generally small, undeformed quartz monzonitic plutons which intrude both the core and the cover.

Post - Eocene Units

TQs - Late Tertiary - Quaternary surficial deposits. This unit is generally unconsolidated alluvium and glacial till which overlies all other units unconformably.

Geologic Evolution

The early history of the Pioneer Mountain is largely unknown. Presumably late-Precambrian rocks were deposited along a passive, Atlantic-type continental margin. Timing of the metamorphic event which produced the Wildhorse Canyon Complex is uncertain. Following the late Devonian - early Mississippian Antler Orogeny the area received clastic sediments from the Antler highlands to the west. A mid-Mesozoic metamorphic event affected the area before Sevier thrusting telescoped the upper Paleozoic sedimentary rocks and carried them northeastward across the region. Clastics deposited in local basins were covered in the Eocene by Challis Volcanic ignimbrites and Tertiary intruded by granites. Many late Tertiary high-angle faults are similar to those in the Basin-Range province (Dover 1969).

URANIUM FAVORABILITY

There are no reported uranium occurrences within the crystalline core of the Pioneer complex. One occurrence is present north of the complex in Paleozoic sedimentary rocks adjacent to an Eocene granite. This granite is characterized by anomalously high radioactivity (220 cps). Another Eocene granite occurs within the crystalline core of the complex and is associated with tungsten mineralization (Cook, 1955, 1956). Limited scintillometry reveals that neither the granite nor the mineralization is anomalous. Metamorphic rocks in the complex have been largely derived from Paleozoic sedimentary rocks. The complex has very low favorability for the occurrence of uranium mineralization.

URANIUM OCCURRENCE

I-507 - Radioactivity occurs at the contact between Eocene quartz monzonite and the Paleozoic Phi Kappa Formation.

ALBION RANGE

GEOLOGY

By

Charles F. Kluth

Introduction

The Albion Range is located in south-central Idaho, east of the Antler orogenic belt and west of the Sevier orogenic belt. The Albions are part of the northern Basin-Range province, just south of the Snake River Plain. They represent a northward extension of the Grouse Creek-Raft River complex of northern Utah. Geologic maps and synthesis of the Albion Range include Armstrong (1968, 1970, 1980) and Miller (1980).

General Geology

The range may be generalized as having a metamorphic core that has been subjected to a complex history of deformation, metamorphism and plutonism. Paleozoic rocks are deformed and metamorphosed, so at least part of the complex history is Mesozoic or younger. Metamorphic grade varies from greenschist to amphibolite facies with a notable increase northwestward and downward in the core. Four arches in the core rocks postdate development of northeast-trending, northwest-verging folds and generally northwest lineation (Armstrong, 1968). The crystalline core is overlain along a low angle tectonic contact by unmetamorphosed upper Paleozoic sedimentary rocks and by Tertiary volcanic rocks (Armstrong, 1968, 1980). The area was intruded by the Almo Pluton, a two-mica ademellite, for which an age of 30 m.y. has been reported (Armstrong, 1968).

Rock Units

Crystalline Core

P€b - Precambrian Green Creek Complex. This unit is characterized by the association: gneiss-schist-amphibolite and by a distinctive porphyroblastic texture. The Green Creek Complex is approximately 2.7 m.y. old and may correlate with the Harrison Formation of the Raft River Range.

PZm - Paleozoic sedimentary rocks which are metamorphosed and lineated to varying degrees. Quartzites and schists generally represent Cambrian and Ordovician siliceous sedimentary rocks such as the Mahogany Peaks Formation. Dolomitic and calcitic marbles and quartzites represent Ordovician and younger (?) Paleozoic rocks.

Tgn - gneiss of probable Tertiary age and possessing variably developed lineation and foliation. This unit includes the gneisses of Camel Rock, Middle Mountain and East Hills.

Tg - Tertiary granitic rocks of the Almo pluton. This unit is a medium grained, two-mica adamellite or granodiorite and has been variably deformed. An undeformed part of this unit has been dated as 30 m.y. old (Armstrong, 1968).

Cover

Pz - Paleozoic sedimentary rocks. This unit includes unmetamorphosed upper Paleozoic sedimentary rocks which are above the detachment surface and includes Mississippian black shales, conglomerates and limestones, Pennsylvanian clastics and Permian limestones.

Tvs - Tertiary volcanic and sedimentary rocks. Rocks in this unit include intermediate to silicic volcanic rocks, sandstones and conglomerates which overlie the complex unconformably. This unit predates the basalts of the Snake River Plain.

Post-Middle Miocene Units

TQb - basaltic rocks of the Snake River Plain.

TQs - Late Tertiary-Quaternary surficial deposits. This unit includes alluvium, basin-fill gravels and glacial fill which are variably consolidated and which overlie the earlier units unconformably.

Geological Evolution

The late Precambrian and early Paleozoic history of the Albion Range can be characterized as deposition of sedimentary rocks on a passive, Atlantic-type continental margin. This setting changed dramatically following the late Devonian-early Mississippian Antler Orogeny. The Antler orogenic belt, uplifted to the west, shed clastic sediments eastward into a deep intracratonic trough, which probably included the Albion region. During the late Paleozoic - early Mesozoic, this area was the site of periodic marine and continental (?) sedimentation.

A period of widespread, high-pressure metamorphism and northwest-overturned folding affected this region in the mid-Jurassic. Following the development of a northeast-trending arch, several allochthonous slices, including one which is upside down, were emplaced over the region in early to middle Cretaceous (Armstrong, 1968). This deformation may be related to development of the Sevier orogenic belt to the east. The Albion Range experienced a mid-Tertiary intrusive and metamorphic event which included flattening and attenuation. Volcanic rocks associated with the Snake River Plain - Yellowstone volcanics were erupted in the late Tertiary and were accompanied by Basin-Range faulting which blocked our present topographic features.

URANIUM FAVORABILITY

There are a variety of uranium occurrences in and around the Albion complex. Several occurrences consist of veins in metamorphic rocks of the Precambrian Green Creek complex. The origin of these veins is uncertain and may be due to either hydrotheral or meteoric fluids. Additional uranium occurrences in the complex are associated with pegmatitic and aplitic phases of the middle Tertiary Almo muscovite granite Armstrong, (1968). The Almo pluton exhibits moderate radio-activity (100-150 cps) but its uranium content is unknown. Other uranium occurrences are located in Paleozoic sedimentary rocks that flank the crystalline core of the complex.

Uranium occurrences are present west of the Albion Mountains in the Goose Creek area (Mapel, 1952; Mapel and Hail, 1959). Mineralization is concentrated in tuffaceous sedimentary rocks of late Tertiary age. Carbonaceous material has locally acted as a precipitating agent. Although these occurrences probably derived their uranium from the interbedded tuffs, similar lithologies might exist at depth along the flanks of the Albion complex. These could have precipitated uranium which had been leached from uraniferous rocks in the core of the complex. This possibility can only be evaluated after extensive deep drilling, along the down-dip extensions of the dislocation surface. Radioactive black sands adjacent to the complex (John R. Reynolds, 1979, personal communication) constitute another type of uranium occurrence. The diversity of occurrences within the complex requires further study to more accurately evaluate uranium favorability of the complex. The Albion Mountains have high uranium favorability compared to most core complexes, but less favorability than either the Kettle or Selkirk complexes.

URANIUM OCCURRENCES

I-350 - Radioactive deposits occur in veins and as replacements in lower Paleozoic sediments and in a granitic porphyry.

I-351 - Radioactivity occurs as mesothermal fissure filling in porphyritic granite.

I-352 - Radioactivity occurs as mesothermal vein and replacement deposits in quartzites, marbles and schists.

I-353 - Radioactivity occurs in the carbonaceous shales of the Salt Lake Formation.

I-354 - Uranium occurs in pegmatites in metamorphic rocks and in the Green Creek Complex and Almo pluton.

I-355 - Radioactivity occurs in pegmatites intruding into the Almo pluton.

I-356 - Uranium occurs as a magmatic hydrothermal deposit in pegmatites of the Almo pluton.

I-357 - Radioactivity occurs in pegmatites of the Almo pluton.

I-358 - The radioactive occurrence is a placer deposit in Quaternary alluvium.

I-359 - Radioactivity occurs in a granitic rock in the Green Creek complex.

I-360 - Uranium occurs as a vein-type deposit in granitic rocks in the Green Creek complex.

I-361 - Radioactivity occurs in granitic rocks in the Green Creek complex.

I-362 - Radioactivity occurs in the sediments of the Salt Lake Formation.

I-363 - Uranium minerals occur in pegmatite.

RAFT RIVER AND GROUSE CREEK MOUNTAINS

GEOLOGY

By

Steven H. Lingrey

Introduction

The Raft River Mountains are an east-west-trending range which deflects at its western end into the north-south-trending Grouse Creek Range. The ranges are situated in extreme northwestern Utah just south of the Idaho border and east of the Nevada border. The Albion Range lies immediately to the north. The Raft River Mountains form an elongate dome, rising about 4000 feet above the valley floor which is approximately 5000 feet above sea level. The Grouse Creeks are a slender, linear range, rising about 3000 feet above the valley floor, and are bifurcated with an intermountain valley to the north. Geological mapping and synthesis has been carried out primarily through the work of Compton and Todd (Compton, 1972, 1975, 1980, Compton and others, 1977, Todd, 1980).

General Geology

The geologic framework of the Raft River and Grouse Creek Mountains has been explained by a stacking of fault-bounded plates (allochthonous sheets) overlying a largely quartzo-feldspathic crystalline, but in part metasedimentary, Precambrian basement. The overlying structural plates maintain, in a general sense, stratigraphic integrity; the bounding faults are parallel or only slightly oblique to stratigraphic layering. The succession of plates include: (1) a lower allochthon of Precambrian (?) through Ordovician metamorphic lithologies composed of drastically thinned marbles, quartzites, and schists which are structurally disrupted by recumbent folds, (2) a middle allochthon composed of variably metamorphosed (locally unmetamorphosed) middle to upper Paleozoic strata; thinning and deformation of the strata is less intense than that observed in the lower allochthon, has been interpreted as the major detachment surfaces separating metamorphic core rocks from weakly to non-metamorphosed cover rocks. Fold structures, principally in the autochthon and the lower allochthon, detail a complex and temporally extensive (mid-Mesozoic (?) to mid-Tertiary) history. Emplacement of the lower allochthon and much of the middle allochthon appears to have occurred by ∿25 m.y.b.p. as metamorphic aureoles about granitic intrusions of this age transect these units. Post-metamorphic movement of middle and upper allochthons occurred between 20 and 12 m.y.B.P. and was eastward directed

Rock Units

Crystalline Core

P€b - Older Precambrian basement of the Raft River Mountains; this unit consists primarily of metasedimentary schists and semi-schistose sandstones with locally predominant intercalated amphibolitic schists. Metamorphosed trondjhemite and pegmatite are intrusive into the schists.

P€a - Metamorphosed Precambrian adamellite; this unit exhibits a textural variation from a granular, igneous-appearing rock to an increasingly foliated gneissic rock. Gneissose textures predominate in the western Raft River Mountains and in the Grouse Creek Mountains. In all areas the foliation becomes more marked upward. Radiometric analysis indicated that adamellite is of probable 2500 m.y.B.P. heritage.

Z€cm - Metamorphosed and commonly intensely foliated latest Precambrian through Early Cambrian strata; predominately quartzites, and pelitic and mafic schists. The lower formations of this unit, considered here to be correlative with the latest Precambrian clastic strata of the Cordilleran miogeocline, may in fact be ∿1700 m.y. old based on lithologic and stratigraphic similarities to rocks of this age in the Wasatch Range.

Pzm - Metamorphosed and commonly intensely foliated lower Paleozoic strata (predominately of Ordovician age); predominately marble tectonite, but includes some Eureka metaquartzite.

Tg - Single to multiple intrustions of adamellitic through granodioritic composition; biotite and locally garnet are prominent accessory minerals. Plutons situated in the lower plate (autochthon and lower allochthon) become sill-like and display foliated (cataclastic) fabrics where proximal to the dislocation surface underlying the upper plate (middle allochthon). Metamorphic aureoles about the stocks, in the central Grouse Creek Mountains cross-cut the contacts between the autochthon, lower allochthon, and middle allochthon. Radioisotopic studies suggest mid-Tertiary (Oligocene) emplacement ages with final cooling in some cases deferred into the Early Miocene. The large multiple intrusion in the southern end of the Grouse Creek Mountains (Immigrant Pass) is situated within the upper plate (middle allochthon); foliate textures are not conspicuous.

Cover

Pz - Weakly metamorphosed to locally unmetamorphosed upper Paleozoic (Devonian through Permian) marine strata of the Cordilleran miogeocline; the majority of this unit is composed of the intercalated silty to sandy carbonate and calcareous sandstone beds of the Pennsylvanian Oquirrh Group. The flat-lying fault at the base of this unit follows closely the stratigraphic horizon of the Mississippian Chainman Shale.

Post Middle Miocene Unit

TQs - Upper Miocene through Quaternary surficial deposits including continental clastics which are locally tuffaceous. Some areas may include older (mid-Tertiary) strata.

Geologic Evolution

During the Paleozoic, the Raft River and Grouse Creek Mountains were situated within the Cordilleran miogeocline accumulating approximately 12 km of sedimentary section over a Precambrian cratonic basement. A depositional hiatus covers much of the post-miogeoclinal history and spans from the Early Triassic to the Late Miocene. Sometime in the Mesozoic, perhaps as early as the middle Mesozoic, dynamothermal metamorphic episodes began to deform the Paleozoic section. This deformation was to an uncertain degree contemporaneous with Sevier and Laramide thrust faulting about 100-150 km to the east. Much of the presently conspicuous lineated and foliated metamorphic fabric, mesoscopic fold structure, gross attenuation of latest Precambrian and lower Paleozoic section, and macroscopic stacking of allochthonous plates is believed to have occurred in the middle Tertiary (especially Late Oligocene). Later, post-metamorphic dislocation of the upper allochthon and to a lesser degree of the middle allochthon continued into the Miocene. Locally (Matlin Mountains area) klippen were emplaced over Miocene sediments as young as 11 m.y.B.P.

URANIUM FAVORABILITY

There is only one reported uranium occurrence in the crystalline cores of the Raft River and Grouse Creek Mountains. Several uranium occurrences lie west of the complex in tuffaceous Tertiary sedimentary rocks; these occurrences probably have little relation to the complex. Little information is available regarding uranium and thorium contents of granitic and metamorphic rocks of the complex. Marjaniemi and Basler (1972) reporteda uranium content of 10.5 ppm for an unspecified granite in the Grouse Creek Mountains. The Raft River and Grouse Creek mountain ranges could be confidently assigned low uranium favorabilities were it not for their proximity to the favorable Albion Range to the north. Additional study of the area is clearly needed.

URANIUM OCCURRENCES

N-154 - Measured section in Tertiary Salt Lake Formation includes 5 ft of carbonaceous shale which is slightly radioactive containing small amounts of uranium.

N-155 - Two carbonaceous shale beds in the Salt Lake Formation (9 ft thick) contain anomalous amounts of uranium.

U-303 - Radioactivity occurs in tuffaceous shales and in rhyolite flows which cap Paleozoic limestones and sandstones.

U-304 - Radioactive occurrence is in a Precambrian(?) metamorphic series of gneiss, phyllite and quartzite.

RUBY AND EAST HUMBOLDT MOUNTAINS

GEOLOGY

By

Steven H. Lingrey

Introduction

The Ruby Mountains are a dramatic, alpine range located in northeastern Nevada. Elevations along the crest typically exceed 10,000 feet above sea level; flanking valleys are at 6,000 feet. The range trends north-northeast and merges at its northern end with the East Humboldt Mountains. This geologic synthesis of the Ruby Mountains is based predominately on the work of Howard (1966, 1971, 1980), Snoke (1980) and Snelson (1957). The map of Howard and others (1979) provides a detailed source for compilation.

General Geology

The predominant geologic element of the Ruby Mountains is not the flat-lying detachment surface so dramatic in other complexes. Instead, large-scale fold and thrust nappes and granitic sills located in the central part of the range dominate the geologic map portrayal. Indeed, the metamorphic-igneous basement of the range displays a complexity greater than that found in many of the other core complexes. In the southern and northern extents of the Ruby Mountains unmetamorphosed Paleozoic and mid-Tertiary volcanic rocks crop out. In the southern Ruby Mountains the relationship between metamorphic basements and unmetamorphosed Paleozoic strata is obscured by Mesozoic and Cenozoic intrusions. In the northern Ruby and southern East Humboldt Mountains, however, a distinctive, flat-lying dislocation surface separates the lower-plate metamorphic rocks from the upper-plate unmetamorphic rocks. Expression and geologic relationships of the flat-lying dislocation surface is similar to the Snake Range décollement.

The metamorphic basement of the Ruby Range is divisible into two zones: 1) a high-grade migmatitic metamorphic core showing large-scale recumbent folding and 2) an overlying intensely strained zone showing a prominent flattening foliation and associated elongation lineation. The boundary between the two zones is transitional; the recumbent folds become oppressed and pass into a braided system of ductile faults. As the basal detachment surface is approached the metamorphic rocks are retrograded and their ductile fabric elements are brecciated.

Areas of upper-plate exposure in the Ruby Mountains are minimal, but show the intense slicing of high- to low-angle faults and predominant younger-over-older relationships that are typical for the core complexes. Mid-Miocene sedimentary and volcanic rocks are involved in this faulting and may locally overlie the metamorphic basement above the flat-lying dislocation surface.

Rock Units

Crystalline Core

Z€cm - Metamorphosed and commonly intensely foliated latest Precambrian through Early Cambrian strata; predominantly quartzites with minor schists.

Pzm - Metamorphosed and commonly intensely foliated Paleozoic strata; predominately marble and dolomitic marble.

MZg - Undifferentiated Mesozoic (?) granodiorite through quartz monzonite sill-like bodies, intimately associated with the nappe structures in the northwestern Ruby Mountains.

JKim - Leucocratic pegmatitic granite and gneiss, and intercalcated marbles; this unit maintains a fairly consistent position stratigraphically, usually between metamorphosed Cambrian dolomitic marble and metamorphosed mid-Ordovician Eureka quartzite and overlying marbles (Pzm).

Jg - Jurassic Leucocratic, pegmatitic granite and gneiss; locally this unit contains two-mica granite and biotite quartz monzonite. Rb-Sr dating techniques indicate an age of approximately 160 m.y.b.p.

Kgm - Cretaceous muscovite granite. Age has been determined as 82 m.y.b.p. by Rb-Sr methods.

Tg - Tertiary Harrison Pass pluton consisting of biotite granodiorite through quartz monzonite composition. Age has been determined at ^38 m.y.b.p. by K-Ar methods.

Cover

Z€c - Unmetamorphosed latest Precambrian through Early

Cambrian marine clastic strata of the Cordilleran miogeocline; the section consists predominately of massively bedded quartzites and siltstones.

Pz - Unmetamorphosed Paleozoic (middle Cambrian through Permian) marine strata of the Cordilleran miogeocline; the middle Cambrian through Lower Mississippian part of the section consists predominately of carbonate strata with only subordinate clastic beds. The Upper Mississippian through Permian part of the section consists of interbedded carbonate and clastic strata. Locally includes some Triassic marine strata.

Tsv - Tertiary sedimentary and volcanic rocks of probable Oligocene through middle Miocene age, but perhaps including some younger Tertiary strata; this unit consists of interbedded conglomerate, sandstone and siltstone (frequently tuffaceous), limestone, and andesitic to rhyolitic tuffs.

Post-Middle Miocene Units

TQs - Undifferentiated units Late Tertiary Quaternary surficial deposits; this unit consists primarily of alluvial, fluvial, colluvial, and tuffaceous sedimentary deposits.

Geologic History

The Phanerozoic history of the Ruby Mountains began with the development of the development of the Cordilleran miogeocline in the latest Precambrian. Deposition more or less continued to the middle Triassic; the Antler and Sonoma orogenies generated hiatuses and modified sedimentation within the section. Thrust faults associated with these events lie approximately 50 km to the west. A stratigraphic gap exists from the middle Triassic through the early Tertiary. In the mid-Tertiary, great thicknesses of ignimbrites and associated continental sedimentary deposits were laid down. Igneous intrusion occurred sporadically throughout the time of the stratigraphic gap. Dynamothermal metamorphism probably began roughly concurrent with the first igneous intrusions sometime in the mid-Mesozoic. The nature and extent of this deformation, however, is uncertain. A chronology of fold systems and associated kinematics can be established in a relative sequence, but the exact timing is constrained only to the time span from mid-Mesozoic to early Tertiary compressive deformation. The intense foliation and associated lineation are probably in most cases associated with mid-Tertiary ductile extension. Generation of the low-angle detachment faults is considered to have begun in the mid-Tertiary and extends into the middle Miocene. In post middle Miocene times, Basin and Range tectonism commenced generating the present horst and graben terrain.

URANIUM FAVORABILITY

Two minor uranium occurrences are reported within the crystalline core of the Ruby - East Humboldt complex. Secondary uranium mineralization in these occurrences is associated with muscovite and garnet-bearing pegmatitic phases of a Cretaceous muscovite granite. Samples of muscovite granite and pegmatite have uranium contents ranging from 2 to 5.4 ppm. In contrast, samples of hornblende- and sphene-bearing Oligocene Harrison Pass granite have between 5 and 9.2 ppm uranium. Uraniferous samples (4-9.5 ppm) reported by Marjaniemi and Basler (1972) have location coordinates that place the samples within the Harrison Pass stock.

A variety of granitic rocks in the range have been mapped inclusively as "Jurassic granite" (Howard and others, 1977). A coarse-grained biotite - granite phase of this map unit exhibits moderate radioactivity (100-150 cps) and has low uranium content (generally less than 1 or 2 ppm). The radioactivity of the granite must be largely due to its very high potassium content (near 6% K_2O) since the granite is depleted in thorium as well as in uranium.

A distinctive biotite monzogranite is also included in the "Jurassic granite" map unit of Howard and others (1979). This rock is characterized by very high background radioactivity (300 to 450 cps) and was observed cross-cutting the coarse-grained granite. Uranium analyses of the monzogranite range from 4 ppm to nearly 14 ppm. Thorium content varies but is typically high (39-98 ppm), averaging 64 ppm. This thorium content is four times higher than that for the average granite (16 ppm) and 50% higher than that for the well-known Conway granite of New Hampshire. There is no known uranium mineralization associated with the Ruby monzogranite. Scintillometry and uranium analyses of calc-silicate rocks injected by the granite reveal no anomalous uranium contents. The monzogranite may have retained most of its magmatic uranium because it was intruded as a relatively dry pluton. It is extremely doubtful that this radioactive monzogranite could be in any way related to the uranium-poor, coarse-grained granite which it intrudes.

The uranium favorability of the Ruby and East Humboldt Mountains is moderate by virtue of the presence of the aforementioned uraniferous granites. The low number of uranium occurrences in the ranges suggests a low uranium favorability. The Ruby Mountains must be studied in more detail with specific emphases placed upon plutonic geology before a definitive conclusion can be reached with regard to uranium favorability.

One further aspect of the mountain range that deserves mention concerns the adjacent basins. East of the complex lies the Ruby Valley which occupies a graben formed by Basin and Range block-faulting. The Ruby Marshes, which are a wildlife refuge, indicate the existance of closed drainage conditions within the graben. It is possible that uranium has been leached from the locally uraniferous plutonic rocks of the Ruby Mountains and reconcentrated at depth below the valley. Such uranium potential may be difficult to evaluate because of logistical and environmental considerations.

URANIUM OCCURRENCES

N-156 - Uraninite and its alteration products were reportedly found near a quart-rich mass in the core of a pegmatite.

N-157 - Autunite occurs along a faulted margin of a beryl-bearing pegmatite.

N-168 - Radioactivity occurs in sediments of the Park City group.

N-170 - Radioactivity occurs in sediments of the Tertiary Humboldt formation.

SNAKE RANGE, SCHELL CREEK RANGE AND KERN MOUNTAINS

GEOLOGY

By

Steven H. Lingrey

Introduction

In east-central Nevada, the Snake Range, the Schell Creek Range, and the Kern Mountains exhibit a complex geologic history. These ranges constitute bold, north-trending mountain chains separated by intervening graben valleys; they are typical expressions of Basin and Range physiography. Valley floors lie over 5500 feet above sea level and the rugged mountains often reach 10,000 feet along their crest. Wheeler Peak in the Snake Range attains an altitude of 13,063 feet above sea level. Geologic studies of the Snake Range and adjacent ranges are abundant. P. Misch (1960) provided the first detailed synthesis of the geology in east-central Nevada, in particular the identification of the flat-lying Snake Range décollement. Subsequent work by students of Misch, geologists at the U.S. Geological Survey, and others have added important, clarifying detail (Misch and Hazzard, 1962; Nelson, 1966; 1969; Drewes, 1958; 1964; 1967; Whitebread, 1969; Lee and others, 1970; Hose and Blake, 1976; Armstrong, 1972; Coney, 1974). Construction of the tectonic map was abstracted from the White Pine County map of Hose and Blake (1976). Interpretation of the structural and metamorphic history in the Snake Range area has been and still is controversial. The view expressed herein follows closely the ideas of Armstrong (1972) and Coney (1974).

General Geology

The geologic framework of the Snake Range area is dominated by a flat-lying, moderately domed dislocation surface, the Snake Range décollement. The Snake Range serves as an almost archtypal example of a Cordilleran metamorphic core complex. The Snake Range décollement is a fault which separates a metamorphic basement of latest Precambrian through Early Cambrian clastics (also locally middle Cambrian marbles) from an unmetamorphosed upper plate of middle Cambrian through Permian marine strata. Often, a variably thick (<3 to 100 feet), intensely foliated crystalline carbonate layer, the marble tectonite, underlies the décollement forming a conspicuous band along the trace of the décollement.

The metamorphic basement of the Snake Range possesses the strong foliation and lineation fabric which typify the crystalline basement terranes of the metamorphic core complexes. Prominent in the metamorphic basement are granitic intrusions in the southern Snake Range; coarse-textured plutons of Jurassic age are intrusive into the latest Precambrian through Early Cambrian clastic strata. Locally, near the décollement, the plutons show cataclastic fabric. Also notable is a progressive reduction in K-Ar isotopic ages towards the décollement (Lee and others, 1970). This has been interpreted as indicative of late Tertiary activity on the Snake Range décollement. In the northern Snake Range and in the Kern Mountains, Tertiary stocks are sporadically intrusive into the metamorphic basement. Similar to the Jurassic plutons, areas near the décollement show cataclasis and reduced K-Ar ages. Of interest, the marble tectonite is observed to underlie the Snake Range décollement where it crosses the plutons. No plutonic intrusions are found in the upper plate.

Upper-plate rocks have been thoroughly sliced by high-to low-angle faults. Displacement on these faults and on the Snake Range décollement have typically emplaced younger rocks over older rocks. Some of the upper-plate faults are listric-normal faults, whose dips flatten with depth, often coalescing with the Snake Range décollement. In the southern and central Snake Range and in the central Schell Creek Range, middle Tertiary strata are cut by these faults.

Rock Units

Crystalline Core

ZꞒcm - Metamorphosed and commonly intensely foliated latest Precambrian through Early Cambrian strata; these rocks are predominately foliated and lineated quartzites.

Pzm - Metamorphosed and commonly intensely foliated Paleozoic (Middle Cambrian) strata; these rocks are predominately foliated carbonate and calc-silicate gneisses.

Pzt - Marble tectonite; intensely foliated crystalline carbonate layer of variable thickness (<3 to 1000 feet) underlying the décollement in the Snake Range. Upper and lower boundaries of the marble tectonite are interpreted as faults. Internally the marble tectonite exhibits cataclastic shearing and strong vertical attenuation. The marble tectonite is absent beneath most of the décollement in the Schell Creek Range.

Jg - Coarse-textured plutons of adamellite through granodiorite composition. Extensive radioisotopic study indicates a middle Jurassic (^ 160 m.y.b.p.) age of crystallization.

Tg - Single to multiple intrusions typically of granitic through granodioritic composition. In several localities (Tgm) the presence of muscovite is conspicuous. Commonly, the primary igneous texture has been converted to a gneissic foliation. Potassium-argon dates on these rocks generally fall within 32-22 m.y.B.P. time span, although it is uncertain how close these dates are to the time of emplacement.

Cover

Z€c - Unmetamorphosed latest Precambrian through Early Cambrian marine clastic strata of the Cordilleran miogeocline; the section consists predominately of massively bedded-quartzites and siltstones.

Pz - Unmetamorphosed Paleozoic (Middle Cambrian through Permian) marine strata of the Cordilleran miogeocline; the Middle Cambrian through Lower Mississippian part of the section consists of interbedded carbonate and clastic strata.

Tsv - Tertiary non-marine sedimentary and volcanic rocks of probable Oligocene through Middle Miocene age; this unit consists of an interbedded sequence of ash-flow buffs, siltstones, sandstones, and conglomerates. In the Sacramento Pass area, the red- and drab-colored conglomerates and interbedded, thick layers of coarse grained monolithologic (Paleozoic clasts) breccia are distinctive. Potassium-argon dates on ash-flows generally fall within a 35-20 m.y.B.P. time span. In the central Schell Creek Range, basal portions of the Tertiary section may correlate with the Eocene lacustrine Sheep Pass Formation.

Post-Middle Miocene Units

TQs - Undifferentiated Late Tertiary-Quaternary surficial deposits; this unit consists primarily of alluvial, fluvial, and colluvial deposits.

Geologic History

The Phanerozoic history of the Snake Range area began in the Late Precambrian with the development of the Cordilleran miogeocline in which over 12 km of marine sediment accumulated.

Deposition ceased by the middle Triassic, a hiatus lasting into the mid-Tertiary when great thicknesses of ignimbrites and associated non-marine sediments were laid down. Tectonism was widespread across the Great Basin from Late Triassic to Late Cretaceous, although the extent to which the Snake Range experienced this is uncertain and controversial. Certain aspects of the metamorphic basement of the Snake Range may date back to the mid-Mesozoic. Sevier-age thrusting to the east appears to have more certainly involved evolution of the Snake Range; it is believed that the basal thrust of the Sevier allochthon roots into basement beneath the Snake Range. Dynamothermal activity in the metamorphic basement, while perhaps originating in the mid- to late-Mesozoic, was certainly active in the mid-Tertiary. In late Oligocene to middle Miocene times, brittle distension occurred in the upper plate along listric-normal faults which shoaled to form the subhorizontal Snake Range décollement. In post-Middle Miocene times, Basin and Range tectonism commenced, generating the present horst and graben terrain.

URANIUM FAVORABILITY

There are no reported uranium occurrences in the Snake Range or Kern Mountains except for locally high uranium contents in accessory minerals of a Jurassic granite. Beryllium mineralization in the Snake Range, and tungsten mineralization in the Kern Mountains are evidently nor uraniferous. Metamorphic rocks in the complex were derived from Paleozoic quartzites and carbonates, both unfavorable source-rocks for uranium. Several granites in the complex have uranium contents (8-10 ppm) which are above that of average granites. However, the large muscovite-bearing Tungstonia granite of the Kern Mountains has below average uranium abundances (Marjaniemi and Basler, 1972; this study). Overall, the Sanke Range and Kern Mountains have low favorability for uranium mineralization.

URANIUM OCCURRENCES

N-441 - 5 square mile area of quartz monzonite dated 145 m.y. contains allanite monazite in amounts from .04-.12 weight %.

WHIPPLE, CHEMEHUEVI, SACRAMENTO,
AND DEAD MOUNTAINS

GEOLOGY

By

Steven H. Lingrey

Introduction

The Whipple, Chemehuevi, Sacramento, and Dead Mountains trend north-northwest along the western (California) side of the Colorado River. They extend about 75 miles from Parker, Arizona on the south to near Bullhead City, Arizona on the north. Needles, California is situated near the midway point of their extent. The ranges comprise variably elongate domes rising from 1500 to 3500 feet above the valley floor. All elevations are well below 5000 feet above sea level. Interestingly, the Whipples are elongate east-west, the Chemehuevis are elongate northeast-southwest, and the Sacramento-Dead Mountains are elongate north-south. Geological maps and synthesis of the geology has been accomplished primarily through the work of G.A. Davis, his colleagues and students at the University of Southern California (Davis and others, 1977, 1979, 1980; Anderson and others, 1979). The geology north of the Whipple Mountains is dependent to a large degree on the unpublished reconaissance mapping of geologists of the Southern Pacific Company.

General Geology

The Whipple, Chemehuevi, Sacramento, and Dead Mountains all exhibit a relatively straight-forward framework; this is expressed by a quartzo-feldspathic crystalline core (lower plate) separated from an overlying, intensely normal-faulted cover of Precambrian basement and mid-Tertiary volcanic and red-bed clastic rocks (upper plate). The plane of separation is a distinctive, flat-lying fault similar to those found in other metamorphic core complexes. The lower plate is commonly an amphibolite-grade mylonitic gneiss showing a low-dipping foliation and northeast-trending lineation; however, in many cases the lower plate consists of "undeformed" (lacking Phanerzoic fabric) Precambrian basement. Late Mesozoic through mid-Tertiary dikes, sills, and plutons intrude these lower-plate rocks. They may or may not be deformed. Upper-plate rocks do not possess the mylonitic fabric and show no evidence of Mesozoic or Tertiary metamorphism. Normal faults in the upper plate usually strike to the northwest with a predominance of northeasterly dips. Mid-Tertiary strata have been rotated on these faults such that they dip to the southwest. Hanging wall displacement is predominately to the northeast. No radial pattern of displacement away from the crests of the ranges has been demonstrated.

Rock Units

Crystalline Core

KTim - quartzo-feldspathic, lineated mylonitic gneisses; lithologies include layered gneisses, foliated plutons, and some hypabyssal dikes. Metamorphic textures of these rocks are, at least in part, of Tertiary origin.

P€mb - Precambrian quartzo-feldspathic core rocks; includes banded gneisses, intermediate granitic rocks and basic to silicic dikes. These rocks display igneous and metamorphic textures of presumed Precambrian heritage, (i.e., lineated mylonitic fabrics typical of most core complex basement rocks are absent).

Cover

P€ma and P€u - Precambrian basement; includes quartzo-feldspathic banded gneisses and subsequent (Precambrian?) intermediate granitic rocks. Diabasic, basaltic, and amphibolitic dikes commonly transect these basement rocks. North of the Whipples, this unit may contain some Mesozoic intrusions.

Mzg - Late Mesozoic leucocratic granites; this unit represents several small calc-alkaline biotite and biotite-muscovite adamellite plutons intrusive into the upper plate Precambrian basement. Two Late Cretaceous K-Ar dates have been obtained from two of the plutons and it is likely they represent the age of emplacement.

Tsv - Mid-Tertiary (late Oligocene through middle Miocene) continental clastics and rhyolite to basaltic andesitic volcanic flows and tuffs. Sedimentary units predominate in the central, northern, and western Whipples and in the southern Chemehuevis. Elsewhere sedimentary and volcanic lithologies are mixed.

Post-Middle Miocene Units

Tc - Non-marine (Osborne Fm.) to locally marine (Bouse Fm.) sedimentary units of late Miocene to Pliocene age. These units overlap and therefore post-date most of the core complex structures of the Whipple Mountains. Similar strata, north of the Whipples, have not yet been recognized.

TQs - Undifferentiated Tertiary-Quaternary surficial deposits; this unit consists primarily of alluvial, fluvial, and colluvial deposits.

Geologic Evolution

The Whipple, Chemehuevi, Sacramento and Dead Mountains were a part of the cratonic platform in Paleozoic through early Triassic times. Paleozoic strata, however, have apparently been removed by subsequent erosion. The Mesozoic Era, geologically much more complex, is nevertheless only partially represented in the rocks of the Whipple, Chemehuevi, Sacramento, and Dead Mountains. The Jurassic and Cretaceous batholithic arc terranes lie fully to the west and to the south of these ranges. The Phanerozoic stratigraphic record in most localities commences with the deposition of Oligocene through Early Miocene non-marine clastics and volcanics on Precambrian crystalline basement. Dynamothermal metamorphism of basement rocks and brittle, extensional faulting of upper plate terranes affected this area in the early (?) and middle Tertiary. In part, this activity was contemporaneous with the deposition of the mid-Tertiary units. By the mid-Miocene (13 m.y.b.p.) most tectonic activity had ceased; mid-Miocene and younger sedimentary deposits overlap these earlier structures. The present day expression of the ranges appears to be due primarily to domical warping in Pliocene and later times. Any associated block faulting appears to be secondary in importance.

URANIUM FAVORABILITY

There are no significant uranium occurrences reported for the southeastern California complexes. Copper and iron mineralization of the region is generally localized along the dislocation zone. The mineralization was evidently not accompanied by significant uranium deposition. Scintillometry of the mylonitic basement and chloritic breccia reveal no major anomalies. The complexes have very low favorability for uranium occurrences.

URANIUM OCCURRENCE

C-650 - Radioactive placers occur in recent sediments.

HARQUAHALA, HARCUVAR, BUCKSKIN, AND RAWHIDE MOUNTAINS

GEOLOGY

By

Stephen J. Reynolds

Introduction

A northwest-trending zone of metamorphic core complexes in west-central Arizona is composed of from southeast to northwest, the Harquahala, Harcuvar, Buckskin, and Rawhide Mountains. These four ranges have a pronounced northeast trend or physiographic grain, in contrast to the north or northwest trends of most mountain ranges in western Arizona. The Harcuvar and Harquahala Mountains are especially prominent in the region because they are fairly high(elevations above sea level of over 5000 feet compared to valley elevations of 2000 feet), northeast-trending ranges. The large northeast-trending McMullen and Butler Valleys bound the Harcuvar Mountains on the south and north sides, respectively. The Buckskin and Rawhide Mountains lie to the northwest and are parts of a single relatively low-relief mountain range. They are separated only by the Bill Williams River; the Rawhide Mountains are situated on the north side of the river.

Early geologic works in the area were of a reconnaissance nature or were concerned with the detailed geology of small mining areas (see references cited in Stanton B. Keith , 1978) and Reynolds, 1980). Laskey and Webber (1947) mapped the geology of the Artillery Mountains (located immediately east of the Rawhide Mountains) and described two important Tertiary sedimentary units: the Artillery and Chapin Wash Formations. Wilson (1960; see also Wilson and Moore, 1959; Wilson and others, 1969) mapped the reconnaissance geology of the entire west-central Arizona region. Shackelford (1976, 1977, 1980) and Gassaway (1972) describe the geology of the Rawhide and Buckskin Mountains, respectively. Rehrig and Reynolds (1977, 1980) discuss results of their reconnaissance geologic and geochronologic studies of the region. They recognized that the Harquahala, Harcuvar, Buckskin and Rawhide Mountains are metamorphic core complexes.

Davis and others (1977, 1979, 1980) integrated the geology of the Rawhide and Buckskin Mountains with that of adjacent areas. Suneson and Lucchitta (1979) determined the ages of volcanic units and tilting in rocks north of the Bill Williams River. Reynolds (1980) synthesized results of unpublished detailed and reconnaissance geologic mapping with that of previous workers, and presented a summary of the geologic framework of west-central Arizona. Reynolds and others (1980) documented major Laramide thrust faults in the Harquahala Mountains, adjacent to an area mapped by Varga (1976, 1977). Geologic research and mineral exploration in the area are continuing at an accelerated pace.

General Geology

The Harquahala, Harcuvar, Buckskin and Rawhide Mountains have essentially all the characteristics that typify Cordilleran metamorphic core complexes. All four ranges are composed of a basement terrane of quartzo-feldspathic gneiss and micaceous schist interlayered with amphibolite, undeformed to well-foliated granitic rocks, and local marble and quartzite. Foliation in the metamorphic rocks is gently dipping and defines large northeast-trending arches which parallel and control the topographic axis of each range. Field and isotopic studies define a major Late Cretaceous to early Tertiary metamorphic event which is probably spatially and temporally associated with plutons of the same age. The metamorphic rocks are most likely derived from Precambrian protoliths, although Paleozoic and Mesozoic sedimentary rocks are also locally incorporated into the basement terrane. Granitic rocks that are interlayered with the metamorphic rocks have Precambrian, Mesozoic and Cenozoic ages.

The metamorphic fabric and associated granites are overprinted by a gently inclined mylonitic foliation that contains a conspicuous northeast- to east-trending lineation. Mylonitic fabric is best developed in structurally high exposures and conforms to the arch defined by the non-mylonitic, metamorphic foliation. The mylonitic fabric is probably early to middle Tertiary in age because it clearly postdates Late Cretaceous - early Tertiary plutons and metamorphic fabric. In addition, mylonitic rocks in the ranges have so far yielded early and middle Tertiary K-Ar biotite and hornblende ages.

The metamorphic - plutonic basement of the Harquahala Mountains has additional structural complexities that have not been described for the other three ranges. For example, much of the range is composed of foliated, porphyritic Precambrian granite which is successively overlain by thrust slices of inverted Paleozoic rocks and Precambrian metamorphic and granitic rocks

(Reynolds and others, 1980). A mylonitic zone associated with one of the thrusts is disconcordantly intruded by early Tertiary muscovite-bearing pegmatites. Elsewhere, these pegmatites exhibit a younger mylonitic foliation that contains the familiar east-northeast-trending lineation. It is uncertain whether basement terranes of the other three ranges were also subjected to such complex structural histories.

In all four ranges, structurally high exposures of mylonitic rocks have been brecciated, jointed, faulted, and affected by retrograde metamorphism or hydrothermal alteration which has formed chlorite, hematite, epidote, sulfides, and copper minerals. This assemblage of rocks and minerals is best termed a chloritic breccia. The chloritic breccia is overlain by a thin (approximately one meter thick) ledge of microbreccia. A dislocation surface is well exposed above the microbreccia throughout much of the Rawhide and Buckskin Mountains and in more isolated exposures along the northeastern ends of the Harcuvar and Harquahala Mountains. The most common allochthonous rocks above the dislocation surface are Oligocene (?) - Miocene conglomerate, sandstone, siltstone and volcanic rocks. However, Precambrian metamorphic and granitic rocks, Paleozoic carbonate and clastic rocks, and Mesozoic igneous and sedimentary rocks are also locally exposed in upper plate positions. Upper plate rocks dip, on the average, moderately to the southwest and are cut by northwest-striking listric-normal faults. Relative tectonic transport of upper plate rocks is mostly to the northeast and is as young as 15 m.y.B.P. (Davis and others, 1980; Rehrig and Reynolds, 1980).

Rock Units

Crystalline Core

P€m - Precambrian metamorphic rocks. These are mostly amphibolite-grade quartzo-feldspathic gneiss, micaceous schist, amphibolite, and interlayered pegmatitic and granitic phases. This unit locally includes fairly large areas of Precambrian plutonic rocks.

P€g - Precambrian granitic rocks. These are porphyritic granites which commonly exhibit a gently inclined foliation and locally grade into augen gneisses.

PZm - Metamorphosed Paleozoic rocks. This unit includes carbonate and clastic rocks which have been metamorphosed to variable degrees.

MZm - Mesozoic metamorphic rocks. These are high-grade gneiss and metasedimentary rocks of possible Mesozoic protolith or metamorphic ages.

Kg - Cretaceous granitic rocks. These plutons range from granodiorite (rarely diorite) to granite. They are typically equigranular and locally foliated. Examples are the Cretaceous Tank Pass granite and Granite Wash granodiorite.

KTim - Cretaceous-Tertiary igneous-metamorphic complex. This unit indicates the crystalline cores of the complexes. It consists of igneous and metamorphic rocks of Precambrian, Mesozic and Cenozoic age that have been metamorphosed in the Cretaceous and Tertiary.

Tgm - Early Tertiary muscovite-bearing granitic rocks. Equigranular muscovite granites are commonly associated with extensive muscovite- and garnet-bearing pegmatite and aplite. The rocks are locally highly foliated.

Cover

P€m - Precambrian metamorphic rocks. These are mostly amphibolite-grade gneiss, migmatite, amphibolite, micaceous schist and other metamorphic rocks.

P€g - Precambrian granitic rocks. These range from equigranular granodiorite to coarsely porphyritic granite.

Pz - Paleozoic rocks. This unit includes carbonate and clastic rocks which are locally metamorphosed.

MZg - Mesozoic (?) granitic rocks. Possible exposures of Mesozoic granite are coarse and porphyritic.

MZsv - Mesozoic sedimentary and volcanic rocks. These are intermediate to felsic volcanics and fine-to coarse-grained clastic rocks. They are locally highly metamorphosed.

Kg - Cretaceous granitic rocks.

Tv - Middle Tertiary volcanic rocks. This unit includes intermediate to felsic volcanic rocks and interbedded volcanogenic sedimentary rocks.

Ts - Tertiary sedimentary rocks. These range from coarse megabreccia-bearing conglomerate to lacustrine sequences dominated by shale, mudstone and opalite. Sandstone is probably the commonest rock type.

Post-Middle Miocene Units

Tb - Tertiary Basalts. These are only slightly tilted and typically cap dark-colored mesas.

TQs - Late Tertiary - Quaternary surficial deposits. These include relatively unconsolidated sediments of alluvial, colluvial, eolian, and lacustrine origin. Some tuffaceous units and evaporite deposits are locally present.

Geological Evolution

In the Precambrian, west-central Arizona was the site of tectonic unrest, crustal construction, and stabilization via a series of depositional, metamorphic and plutonic episodes. Deposition of clastic and volcanic rocks was closely followed by metamorphism, deformation, and plutonism around 1.6 to 1.7 b.y.B.P. Besides possible emplacement of diabasic intrusions in late Precambrian time, the next youngest rocks in west-central Arizona are Paleozoic. Equivalents of younger Precambrian Apache Group rocks are evidently absent from the area. Paleozoic rocks are a relatively thin sequence of carbonate and clastic rocks that represent a cratonic platform environment.

After the Paleozoic interval of relative tectonic quiescence, the area experienced major mid-Mesozoic volcanism, plutonism, and tectonism. The mid-Mesozoic plutons and volcanic rocks are parts of a subduction-related (?), northwest-trending magmatic arc. After the mid-Mesozoic arc swept or jumped westward, thick sequences of clastic rocks were deposited unconformably on the volcanic rocks. Clastic sedimentation was followed by plutonism and metamorphism in the Late Cretaceous and Early Tertiary as magmatism swept eastward across Arizona. Metamorphism was, in part, synchronous with plutonism, and formed high-grade gneissic and migmatitic terranes that are exposed in the metamorphic core complexes. This was sucessively followed by northward-vergent Laramide thrusting and intrusion of early Tertiary muscovite-bearing granites. Mylonitization in the core complexes postdates these events and is early or middle Tertiary in age.

A period of widespread early Tertiary erosion was followed by deposition of middle Tertiary conglomerates, sandstone, siltstone, lacustrine units and volcanic rocks. Plutonism and extensive thermal disturbances accompanied the volcanism. Middle Tertiary rocks were tilted and rotated during dislocation and listric-normal faulting. Final cooling in the core complexes occurred at this time. Block-faulting formed the present-day basins and ranges between 14 and 5 m.y.B.P. Variably sized clastics were shed into the downdropped basins; evaporites were deposited in some closed basin. The region was moderately tectonically stable when the Pliocene Bouse Formation was deposited in a partly marine embayment accompanying development of the Gulf of California. Basins that had earlier been characterized by internal drainage became interconnected as part of the integrated Colorado-Gila River system.

URANIUM FAVORABILITY

There are a significant number of uranium occurrences in west-central Aizona, both within and adjacent to the metamorphic core complexes. Several important occurrences of mineralization lie east of the Harquahala Mountains in the Black Butte area. These occurrences consist of secondary uranium minerals (such as carnotite) that are concentrated in Miocene lacustrine units. Bedding in the Tertiary units dips southwest, probably as a result of listric-normal faulting that accompanied Miocene dislocation; the dislocation surface most likely occurs at depth below the mineralized rocks. The similarity of the mineralization to that at the Anderson mine (in the Date Creek Basin) suggests that volcanism may be the source of the uranium.

The crystalline core of the Harquahala Mountains contains no reported uranium occurrences. Precambrian metamorphic rocks, coarse-grained Precambrian granite, Paleozoic sedimentary rocks, Eocene(?) muscovite granite and pegmatite, and middle Tertiary microdiorite dikes compose most of the complex; none have anomalous uranium contents. Copper mineralization is locally associated with the microdiorite dikes, but a microdiorite sampled by us has a very low uranium content. The muscovite granite and pegmatite exhibit low radioactivity (80 cps) and possess low uranium contents (approximately 1 ppm on the average). Higher uranium contents are present in granite (9.6 ppm) and gold-copper-tungsten mineralization (6.8 ppm) near the Socorro mine (at the western end of the range). Overall, the Harquahala mountains exhibit a very low favorability for uranium occurrences. Lacustrine deposits peripheral to the northeastern end of the mountain range are an exception to this conclusion.

The Harcuvar mountains have several uranium occurrences which are spatially associated with copper-gold mineralization near middle Tertiary microdiorite dikes. Uranium contents of late Cretaceous granodiorite and granite are low to moderate (less than 1 ppm to 4.5 ppm), except for a garnetiferous aplite (20 ppm). Metamorphic rocks in the complex exhibit low to moderate radioactivity (80-150 cps) with mica schist being the most radioactive rock type. Middle Tertiary volcanic and sedimentary rocks in the Bullard Peak area contain copper and manganese mineralization and have recently (circa 1977) been explored for uranium, evidently unsuccessfully. We observed no uranium anomalies in the Tertiary rocks of the Bullard Peak area. The Harcuvar Mountains have low favorability for uranium.

The Buckskin and Rawhide Mountains contain several uranium occurrences located near or within the dislocation zone. Hematite, limonite, copper and gold mineralization commonly occur along the dislocation zone both in areas of uranium concentration and over a much wider area. The uranium potential of these zones is presently unknown. Probably of more significance are uranium occurrences that have been found in upper-plate Tertiary lacustrine units. The present structural configurations of the Lincoln Ranch and Artillery Peak areas are partially the result of dislocation related processes. The same may be true for the Anderson mine. Uranium mineralization may be due to alteration of uraniferous volcanic ash.

The crystalline cores of the Buckskin and Rawhide Mountains have an unresolved (but probably moderate to low) potential for uranium occurrences. The northeastern margins of the ranges have good favorability of Tertiary lacustrine uranium deposits (similar to Anderson mine). The uranium potential of the chloritic, hematitic and pyritic(?) dislocation zone <u>below</u> these lacustrine rocks should be evaluated by deep drilling. The Butler and McMullen Valleys were partly formed by synclinal warps in the dislocation zone and underlying mylonitic foliation. These valleys may be favorable for dislocation-zone-related uranium occurrences. The Buckskin and Rawhide Mountains have moderate uranium favorabilities with respect to other core complexes.

URANIUM OCCURRENCES

A-104 - Radioactivity occurs in a granite that has intruded a granitic gneiss.

A-107 - Radioactivity occurs in beds of mudstone and sandstone of the Tertiary Artillery Formation.

A-113 - Radioactivity occurs in a pegmatite within Precambrian(?) metamorphic rocks.

A-148 - Radioactivity occurs as fracture coatings in the Tertiary Artillery Formation (mudstone and sandstone).

A-163 - Radioactivity occurs as fracture coatings in brecciated sedimentary rocks near a "thrust" fault.

A-171 - Uranium occurs as disseminations in Precambrian granite-gneiss adjacent to a fault.

A-502 - Radioactivity occurs in bedding planes of Tertiary lake beds which are capped by basalts and are intruded by a dike.

A-503 - Radioactivity occurs in granitic placer sands.

A-504 - Uranium mineralization occurs on fracture surfaces on a shaley marl which is underlain by "Precambrian metamorphic rocks" and overlain by thin basalt flow.

A-513 - Radioactivity occurs in fractures and in bedding planes in Tertiary lake beds.

A-520 - Radioactivity occurs in fractures and in bedding planes in a laminated shale capped by lava flows.

A-527 - Radioactivity occurs in tuffs of Tertiary lake beds.

A-902 - Radioactivity is associated with fissures and faults cutting granite and schist. The fault and a dike strike N50W and dips 50°NE.

A-906 - Radioactivity is associated with a fault-vein in a granitic intrusive.

A-914 - Radioactivity occurs in an E-W-trending fault that cuts granite and schist

A-923 - Rock types include Precambrian granites and gneiss and later sediments intruded and capped by Tertiary volcanics. Radioactivity "shows in the pink gneiss."

WHITE TANK MOUNTAINS

GEOLOGY

By

Stephen J. Reynolds

Introduction

The White Tank Mountains are an irregularly shaped range that is located west of Phoenix in central Arizona. The base of the range has an elevation near 1500 feet above sea level while several of the highest peaks reach elevations of over 4000 feet. The Tonopah Desert and ephemeral Hassayampa River valley bound the range on the west and the Gila River valley lies immediately to the south.

Geology of the range was mapped in reconnaissance fashion by Moore (in Wilson and others, 1957), but no written description of the range resulted from that study. Since that time, much of the range has been mapped in reconnaissance and detail by the author. Preliminary accounts of the geology of the range are contained in Rehrig and Reynolds (1980). The descriptions included below are from the ongoing research of Reynolds and others.

General Geology

The crystalline core of the White Tank Mountains is composed of Precambrian metamorphic rocks and a series of younger granitic rocks of Precambrian, Mesozoic, and Cenozoic age. The Precambrian metamorphic rocks consist of amphibolite-grade, quartzo-feldspathic gneiss and biotitic schist derived from sedimentary and igneous protoliths. They typically exhibit their original Precambrian foliation which strikes northeast and dips moderately to the southeast. In the southern foothills of the range, the metamorphics are intruded concordantly by a granodioritic to quartz dioritic pluton. The deformed granodiorite is probably Precambrian because it was evidently intruded during the Precambrian metamorphic-deformational event.

In the northeastern and western parts of the range, equigranular granodiorite, biotite granite, and muscovite-bearing alaskite, pegmatite and aplite intrude discordantly across the foliation of Precambrian rocks. These plutons are almost assuredly Cretaceous or Tertiary. These young plutons as well as their Precambrian host rocks have been subjected to an episode of mylonitization which has imparted onto the rocks a gently to moderately inclined foliation which contains the familiar WSW- or ENE-trending, conspicuous lineation. All rock units of the range described above are dissected by a phenomenal swarm of locally foliated, NNW- and WNW-trending dikes of microdiorite, granodiorite and more felsic lithologies. Intensely brecciated rocks similar to the chloritic breccia zone of other complexes are present on the northeast and southern extremeties of the range, but no dislocation surface has yet been identified. Preliminary geochronologic data of Rehrig and Reynolds (1980 and unpublished) document Tertiary cooling in some parts of the complex.

Rock Units

Crystalline Core

P€m - Precambrian metamorphic rocks: consisting of biotite schist, quartzo-feldspathic gneiss and interlayered granitoid and pegmatitic rocks.

P€g - Precambrian granitic rocks: commonly foliated granodiorite and a younger porphyritic granite.

KTg - Cretaceous and/or Tertiary granitic rocks: variably foliated, ranging from biotite granodiorite to muscovite granite.

Cover and Post-middle Miocene units

Tsv - Middle Tertiary sedimentary and volcanic rocks of uncertain age and relation to core complex events.

TQs - Late Tertiary - Quaternary surficial deposits: consisting of relatively unconsolidated alluvial, colluvial, and eolean sand, silt and coarser detritus.

Geological History

In the Precambrian, sedimentary and volcanic rocks were deposited, metamorphosed, and intruded by several generations of plutons. During the Paleozoic, the area was probably part of cratonic North America; thereby receiving a thin cover of sedimentary rocks. The Mesozoic history of the region is uncertain, but some granodiorites in the range may be latest Mesozoic

(Laramide). In the Tertiary, several types of granites were intruded and were subjected along with their wall rocks to an episode of mylonitization. Middle Tertiary (?) dikes in the range were intruded before, during, and after mylonitization. Tertiary arching of the mylonitic foliation was followed by Basin and Range block faulting which resulted in the deposition of evaporitic and clastic rocks in the adjacent Phoenix Basin. The Gila and Hassayampa Rivers assisted in the sculpturing of the present landscape of the region.

URANIUM FAVORABILITY

There are no reported uranium occurrences in or near the White Tank Mountains. Limited scintillometry in the mountains indicates that Precambrian rocks emit relatively low total counts (60 cps) and that Phanerozoic granitic rocks are only slightly higher (60 to 90 cps). There is very little mineralization of any kind exposed in the range. The White Tank Mountains are considered to have very low favorability for uranium deposits.

SOUTH MOUNTAINS

GEOLOGY

By

Stephen J. Reynolds

Introduction

The South Mountains are located immediately south of Phoenix in central Arizona. They are a northeast-trending range approximately 20 km long and 4 km wide with about 500 meters of topographic relief. The range is isolated from other bedrock exposures, being surrounded by a low-relief surface underlain by late Tertiary-Quaternary surficial deposits.

Although the South Mountains were briefly mentioned by several early geologists, they were first reconnaissance mapped by Wilson (in Wilson and others, 1957; Wilson, 1969). Avedisian (1966) studied petrology of selected rocks in the western half of the range. The first detailed map and discussion of the geology of the range was done by Reynolds and colleagues (Reynolds and others, 1978; Reynolds and Rehrig, 1980; Reynolds, in progress). They recognized that the South Mountains have many characteristics similar to metamorphic core complexes (see Reynolds and Rehrig, 1980). The following discussion of geology of the area is extracted from the published and ongoing studies of Reynolds and others.

General Geology

Precambrian rocks exposed in the western half of the South Mountains consist of amphibolite-grade gneiss and schist with local intrusive masses. Almost the entire eastern half of the range is underlain by mid-Tertiary granodiorite which generally displays a weakly to strongly developed mylonitic foliation. In the center of the range a locally foliated mid-Tertiary granite intrudes between the Precambrian amphibolite gneiss and the granodiorite. Throughout most of the area, Precambrian rocks and the two mid-Tertiary plutons are intruded by numerous northwest-trending, mid-Tertiary dikes which are, in many places, mylonitically foliated. In the northeastern portion of the mountains, the mylonitic granodiorite becomes progressively jointed, brecciated, chloritic, and hematitic up structural section until it is converted into chloritic breccia. In the southern foothills of the mountains, the chloritic breccia is overlain by a low-angle dislocation surface, above which lie Precambrian metamorphic rocks similar to those exposed further to the west.

Rock Units

Crystalline Core

P€m - Precambrian metamorphic rocks. This unit contains amphibolite-grade gneiss and schist with local intrusive masses. Dominant lithologies include amphibolite, quartzo-feldspathic gneiss, and mica schist.

Tg - Tertiary granitic rocks. Granitic rocks in the eastern half of the range are part of a granodioritic pluton of middle Tertiary age (25 m.y.B.P.). Slightly younger rocks of granitic composition are exposed in the center of the range. Both the granodiorite and granite are commonly weakly to strongly mylonitic. Near the northeastern end of the mountains, the granodiorite is converted into chloritic breccia.

Post-Middle Miocene Units

TQs - Late Tertiary - Quaternary surficial deposits. This unit is comprised of relatively unconsolidated sediments of alluvial, colluvial, and eolian origin.

Structural Relationships

Most rocks in the range exhibit a gently dipping mylonitic foliation which contains a pervasive N60E-trending lineation. The foliation is defined by planar mineral aggregates and thin bands of intensely granulated and recrystallized rock. Mylonitically foliated rocks contain joints, quartz-filled tension fractures, and "ductile normal faults" which mostly strike NNW, perpendicular to lineation. Inclusions in deformed plutonic rocks are elongated parallel to lineation and flattened perpendicular to foliation. Folds are rare in mylonitic plutonic rocks, but are more abundant in mylonitically deformed Precambrian amphibolite gneiss.

Gently dipping mylonitic foliation defines an asymmetrical northeast-trending, doubly plunging arch or dome. The foliation generally dips less than 20° where it is contained within plutonic rocks, but is more steeply dipping where it affects Precambrian amphibolite gneiss. The simple pattern of the arch is interrupted on its northeast end where southwest-dipping foliation is present. This attitude of foliation is restricted to structurally high rocks which are chloritic, jointed, and brecciated.

Excellent exposures in the range display the three dimensional distribution of mylonitic fabric and variations in its intensity. Both the granite and granodiorite are undeformed in the core of the arch except for jointing and minor faulting. However, both plutons exhibit a gradual increase in intensity of mylonitic fabric toward the top and margins of the arch (up structural section). A similar distribution of mylonitic fabric is revealed where mylonitization affects Precambrian amphibolite gneiss. In the core of the range near the granite contact, the amphibolites possess a Precambrian foliation which is generally nonmylonitic, northeast-striking, and steeply dipping. The intensity of mylonitic deformation increases upward from the core to several 15 m-thick zones of northeast-lineated, mylonitic gneiss that cut equally thick zones of much less mylonitic amphibolite. Importantly the mylonitic fabric also decreases in intensity upward from the main zones of mylonitic rock. At high structural levels in the western parts of the range, foliation in the amphibolite gneiss is again nonmylonitic, generally east- to northeast-striking, and steeply dipping.

NNW-striking dikes are likewise undeformed in the core of the arch. They are also generally undeformed where they intrude rocks with moderately well-developed mylonitic fabric. However, in structurally high parts of the range where adjacent rocks are intensely deformed, the dikes locally exhibit a gently inclined mylonitic foliation and ENE-trending lineation. Undeformed dikes are commonly near well-foliated dikes of similar lithology and strike.

Another important lithological and structural transition is exposed along the northeast end of the range where mylonitic granodiorite grades upward into chloritic breccia. Structurally lowest exposures of the granodiorite in this area are nonchloritic and well foliated. Up section, chlorite and anastomosing, curvi-planar joints are present in the granodiorite. The rocks are progressively more jointed and brecciated higher in the section where they ultimately grade into chloritic breccia. Remnants of mylonitic foliation in the granodiorite are preserved in the breccia. Relic mylonitic foliation in the breccia generally dips to the southwest, indicating that total disorientation and random rotation of the foliation did not occur, except locally. Joints, breccia zones, and normal faults (northeast side down) have variably northwest strikes. Slickensides in the breccia have scattered, but dominantly northeast trends. In the southern foothills of the range, the chloritic breccia is overlain by a dislocation surface which dips gently to the northeast. Upper plate rocks above the dislocation surface are Precambrian metmorphic rocks which locally have a mylonitic fabric.

Geological Evolution

Reynolds and Rehrig (1980) have discussed geological evolution of the South Mountains. Around 1.7 b.y. ago Precambrian sediments and volcanics were deposited and subsequently metamorphosed and deformed into a steep northeast-striking foliation. Granitic rocks in the westernmost parts of the range may be representatives of the 1.45 b.y. old suite of granites which are common in Arizona. There are no Paleozoic or Mesozoic rocks in the range. Around 25 m.y. ago, the Precambrian rocks were successively intruded by the granodiorite and granite. At this time the plutons and the Precambrian metamorphics were subjected to deformation which formed a low-angle mylonitic foliation containing a northeast-trending lineation. NNW-striking dikes were intruded both during and after mylonitization. Strain indicators in the mylonitic rocks require that during mylonitization, the rocks were vertically flattened and extended parallel to the lineation. After mylonitization, the chloritic breccia was formed in the response to northeast movement of rocks above the dislocation surface. Normal, dip-slip movement is suggested by structures in the upper plate rocks and underlying chlorite breccia. Arching of the mylonitic foliation and chloritic breccia is probably one of the last events in the range. It was followed by the Basin and Range disturbance in which steep normal faults down-dropped the adjacent Phoenix basin around 14 to 8 m.y. ago. Since 8 m.y., the area has been tectonically quiet and geological developments have been dominated by erosion and deposition.

URANIUM FAVORABILITY

There are no occurrences of uranium reported in or near the South Mountains. Scintillometry in the range indicates relatively low total counts for Precambrian metamorphic rocks (40-60 cps) and Tertiary granitic rocks (70-100 cps). Gold and copper mineralization is locally present in the range but is evidently not anomalous in uranium content. The South Mountains have very low potential for significant uranium occurrences.

PICACHO MOUNTAINS

GEOLOGY

By

Charles F. Kluth

Introduction

The Picacho Mountains are located approximately 60 km northwest of Tucson, Arizona and just northeast of the prominent Picacho Peak. The range trends northerly and may be a block faulted extension of the Catalina-Rincon-Tortillita complex. The Durham Hills, Suizo Hills and Desert Peak, which are located between the Picacho and Tortillita Mountains, are probably part of the same terrane. Principal work on the Picacho Mountains and smaller features nearby is that of Yend (1976), Banks and others (1977), Banks (1980), Davis (1980) and Rehrig and Reynolds (1980).

General Geology

Mylonitic gneiss and foliated plutonic rocks compose most of the Picacho Mountains. These rocks possess a low-angle mylonitic foliation with a penetrative northeast-trending lineation. A diffuse north-trending arch in the foliation is exposed in the southern end of the range. A few occurrences of chloritic breccia are interpreted to be the remnants of a dislocation surface near the crest of the range. The surface is exposed in one location where it is overlain by middle Tertiary alkalic volcanics similar to those on nearby Picacho Peak. Rehrig and Reynolds (1980) suggest that the volcanics of Picacho Peak overlie a similar dislocation surface. The north end of the Picacho Mountains contain a granodiorite pluton which has yielded mid-Tertiary K-Ar ages (Rehrig and Reynolds, 1980).

In the Durham and Suizo Hills area, a mylonitic foliation which dips gently eastward has been superimposed on Tertiary (?) and Precambrian (?) plutonic rocks. Mid-Tertiary volcanic and sedimentary rocks lie above these foliated rocks and are separated from them by a chloritic breccia and dislocation surface. Mylonitic fabric decreases in intensity in structurally low parts of the plutonic rocks (Rehrig and Reynolds, 1980).

Rock Units

Crystalline Core

P€m - Precambrian metamorphic rocks. This unit includes schists and gneisses of the Precambrian Pinal Schist, which generally display a steeply dipping foliation.

P€gc - Precambrian granitic rocks. This unit includes coarsely crystalline, porphyritic granodiorite and granite probably similar to the 1.4 b.y. old Oracle Granite.

Tgm - Tertiary (?) muscovite granite. This rock commonly has a well-developed mylonitic foliation.

Cover

Ts - Tertiary sedimentary rocks. This unit includes Tertiary medium- to coarse-grained clastic rocks which are variably consolidated.

Tv - Tertiary volcanic rocks. This unit includes Tertiary silicic to intermediate volcanics.

Post-Middle Miocene Units

TQs - Late Tertiary - Quaternary surficial deposits. This unit represents alluvial, colluvial, and eolian sediments which are generally unconsolidated and overlie older rocks unconformably.

Geologic Evolution

Precambrian metamorphic rocks, probably derived from pelitic and silicic sedimentary rocks, were metamorphosed (1.7 b.y.B.P.) and subsequently intruded by the coarse grained Oracle Granite (1.45 b.y.B.P.). Since no pre-Tertiary Phanerozoic rocks are preserved in the area, the Paleozoic and Mesozoic history is uncertain. Probably, the Picacho Mountains were part of the cratonic shelf that is documented for the rest of southern Arizona. Mid-Tertiary plutonism, volcanism and thermal activity all reflect tectonism which preceeded late Tertiary Basin-Range faulting.

URANIUM FAVORABILITY

There are no reported uranium occurrences in the Picacho Mountains. Copper mineralization in the Lone Star district is evidently not characterized by high uranium contents. Limited scintillometry of mylonitic granitic rocks reveals no anomalies. Scintillometric traverses through the dislocation zone indicate no appreciable variation in total count between chloritic breccia and its mylonitic protolith. The Picacho Mountains have very low favorability for uranium occurrences.

SANTA CATALINA, RINCON, AND TORTOLITA MOUNTAINS

GEOLOGY

By

Stephen J. Reynolds

Introduction

The Santa Catalina Mountains are an impressive, rugged range that lies north of Tucson, Arizona. Highest areas of the range are over 9000 feet above sea level, while the adjacent Tucson basin has elevations near 2500 feet. The Rincon Mountains, a southeastern continuation of the Santa Catalina Mountains, are located east of Tucson. The Tortolita Mountains are a relatively subdued range situated northwest of the Santa Catalina Mountains. There have been numerous geological studies in the three mountain ranges. The essentials of the geology are discussed by Banks (1980) Davis (1980) and Keith and others (1980). These three papers reference most of the pertinent previous studies.

General Geology

The crystalline core of the Santa Catalina - Rincon - Tortolita complex is dominated by Cretaceous and Tertiary plutonic rocks. These comprise a large composite batholith within which at least ten individual plutons have been delineated (Keith and others, 1980). At least some of these plutons are compositionally zoned and display asymmetrical latholithic geometries. The plutons, along with their host rocks, have been affected by a series of mylonitic deformations which have imposed a gently inclined mylonitic foliation on the rocks. The crystalline core of the complex is completely fault bounded except for segments of its north and northeast sides which are intrusive in nature.

The Santa Catalina portion of the complex has received the most intense study. The southern part of the range (Santa Catalina forerange)is comprised of interlayered dark and light gneissic bands of variable thickness. The dark layers are composed of biotite-rich, mylonitic granite and gneiss, mylonitic diortie gneiss, and mylonite schist and amphibolite. Layers and lenses of metasedimentary rocks are locally present. The above rocks are interlayered with, contained within or injected by abundant light-colored layers and dikes of granite and pegmatites. Most of the rocks in the forerange are deformed by a pervasive low-angle mylonitic foliation which contains a conspicuous northeast-trending lineation. Gently-dipping mylonitic foliation in gneisses deep in the forerange arch are structurally the lowest exposed rocks in the complex. Up structural section to the south, the gneisses become jointed, brecciated and chloritic. The chloritic breccia is overlain by the Catalina fault (Pashley, 1966), a dislocation surface which dips gently to the south. Tilted mid-Tertiary sedimentary rocks lie above the dislocation surface. Up structural section to the north of the forerange, the proportion of dark-colored mylonitic granite and diorite gneiss gradually decreases until the rock is entirely a light-colored, mylonitic, two-mica granite of Eocene age. Further up section, mylonitic fabric in the granite becomes less intense and in many places the rock is an undeformed biotite-muscovite-garnet-bearing granite (Wilderness granite of Shakel, 1978). To the north, the upper parts of the granite commonly grade into alaskite and pegmatite (Lemmon rock leucogranite of Shakel, 1978). The entire sill complex from the lowest exposed levels in the forerange to the crest of the main range is over 4.5 km thick. At the top of the sill, pegmatite and alaskite associated with the leucogranite intrude late Cretaceous Leatherwood quartz diorite and adjacent Precambrian sedimentary (Apache Group) and diabasic rocks. The quartz diorite and its intruded cover of Apache Group and Paleozoic strata are terminated to the north by the Geesman fault and a low-angle normal fault mapped by Creasey and Theodore (1975). North of these faults, exposed rocks are more typical of southern Arizona geology; that is, approximately 1.7 b.y. Pinal Schist; 1.5 b.y. old Oracle Granite and less metamorphosed Apache Group, Paleozoic and Mesozoic strata; all intruded by presumed Laramide age granodiorite porphyry and mid-Tertiary porphyritic sphene-bearing, hornblende-biotite Catalina granite. At the far north end of the range, the Mogul fault juxtaposes these rocks against the Oracle Granite of the upthrown northern block.

The western termination of the range is along the Pirate fault, a NNE-trending fault of late Tertiary age. Except for the alluvium-covered interval west of the Pirate fault, much of the Santa Catalina Mountains geology continues westward into the Tortolita Mountains (Budden, 1975; Banks and others, 1977; Keith and others, 1980; Davis, 1980). In this range, arches in mylonitic foliation are difficult to place precisely, but probably exist. The northern part of the crystalline core in the Tortolita Mountains is occupied by the Late Cretaceous(?) Chirreon Wash granodiorite, an ENE to EW-trending composite pluton with quartz diorite, granodiorite and quartz monzonite phases. Intruding the granodiorite in its western exposures are abundant tabular bodies of Eocene (?) granite, pegmatite and alaskite (Derrio Canyon granite). These plutons are locally mylonitic and bordered by east-west-trending schistose bands on both the north and south. To the north, the schistose rocks are in contact with mylonitized Oracle Granite. Further to the northwest, both Oracle Granite and the schistose rocks are chloritized, brecciated and overlain by a dislocation surface. Above the dislocation surface are Precambrian crystalline rocks and middle Tertiary sedimentary and volcanic rocks. The schistose band that borders the Chirreon Wash pluton on the south is intruded on its south side by an ENE-trending mass of mid-Tertiary Catalina (?) granite.

The granite is intruded by numerous apophyses of the Tortolita quartz monzonite pluton that crops out to the south. Both the Catalina and Tortolita intursions locally contain a low-angle mylonitic foliation. The plutons are intruded by NW-striking, undeformed-to-locally-foliated granodiorite, quartz monzonite and quartz latite dikes.

The Rincon Mountains are geologically more similar to the Santa Catalina Mountains than they are to the Tortolita Mountains. A large portion of the Rincon Mountains is composed of muscovite-garnet-bearing granite (Wrong Mountain Quartz Monzonite of Drewes, 1977). The granite commonly envelops a dark, biotitic augen gneiss (Continental Granodiorite of Drewes, 1977). Some parts of the granite have abundant pegmatite and alaskite. Both the granite and the darker augen gneisses exhibit the distinctive low-angle mylonitic foliation. This mylonitic gneiss complex is overlain to the northeast by metamorphosed and locally highly deformed younger Precambrian and Paleozoic rocks which becmome lower grade and less deformed up section (Drewes, 1974; Davis, 1975; Drewes, 1977). The low-angle mylonitic fabric has been deformed into several broad WSW-ENE plunging arches and one NNW-SSE-trending arch.

Rock Units

Crystalline Core

P€gc - Precambrian granite. These plutons are generally coarse grained and markedly porphyritic. In general, they display a strongly mylonitic fabric in the core of the complex. They are probably 1.45 b.y. old and equivalent to the Oracle Granite.

P€s - Precambrian sedimentary rocks and associated diabase. This unit includes variably metamorphosed Apache Group clastic and carbonate rocks and interlayered diabasic sills.

Pzm - Metamorphosed Paleozoic rocks. These are generally carbonate and clastic rocks which are metamorphosed, especially near intrusive bodies.

KTg - Late Cretaceous - early Tertiary (Laramide) granitic rocks. These are mostly granodioritic plutons with dioritic border phases. They are locally highly foliated.

Tgm - Early Tertiary muscovite-bearing granite. This includes a large compositionally zoned pluton which ranges in lithology from biotite granite and granodiorite to muscovite-garnet leucogranite. Pegmatitic and aplitic phases are abundant near the roof of the pluton. Most of the pluton exhibits a gently inclined mylonitic foliation.

Tm - Tertiary mylonite schist. This unit denotes schistose rocks that display a mylonitic fabric and are of uncertain ancestry.

Tg - Middle Tertiary granite. This unit includes several distinct plutons of middle Tertiary (25 m.y.B.P.) granite. They are locally strongly mylonitic.

Cover

P€m - Precambrian metamorphic rocks. These are mostly schist and gneiss which have been assigned to the Pinal schist. They typically exhibit a steep, northeast-striking foliation.

P€gd - Precambrian granodiorite. These plutonic rocks are generally equigranular and 1.6 to 1.7 b.y. old.

P€gc - Precambrian granitic rocks. These are generally porphyritic, coarse-grained, and 1.45 b.y. old.

Pz - Paleozoic rocks. These consist of carbonate and clastic rocks which are typically unmetamorphosed.

Ks - Cretaceous sedimentary rocks. This unit includes conglomerates, finer-grained clastic rocks, and rare carbonate rocks. Most outcrops are probably correlative to the Bisbee Group.

Tv - Middle Tertiary volcanic rocks. These range from basaltic andesite to rhyolite in composition.

Ts - Tertiary sedimentary rocks. These are generally coarse- to fine-grained clastic rocks of middle Tertiary age.

Post-Middle Miocene Units

TQs - Late Tertiary-Quaternary surficial deposits. This unit includes relatively unconsolidated sediments of alluvial, colluvial, and eolian origin, Tuffaceous lithologies are locally present.

Geological Evolution

During the Precambrian, southern Arizona was the site of crustal construction via sedimentation, metamorphism, and magmatism. The region became stable by middle Proterozoic when sediments of the Apache Group were deposited; this was succeeded and accompanied by diabasic intrusions. During the Paleozoic, the entire region was part of a broad cratonic platform which received a thin sequence of carbonate and clastic rocks. Evidence of middle Mesozoic tectonism and magmatism is abundant south of the Tucson area. This interval of tectonic unrest was followed by deposition of marine sedimentary rocks of the middle Cretaceous Bisbee Group. In the late Cretaceous, the Laramide orogeny was manifested in compressional deformation, volcanism, plutonism, porphyry copper mineralization, and syn-tectonic sedimentation. Several granodiorite plutons in the crystalline core of the complex were emplaced during this time. In the Eocene, voluminous muscovite granites were intruded into the complexes and were subsequently mylonitically deformed. Middle Tertiary plutonism in the complex was accompanied by widespread mylonitization in and around the plutons. Final cooling of the complex and movement on marginal dislocation surfaces occurred subsequent to this plutonism. This was shortly (?) followed by arching of mylonitic foliations and of dislocation surfaces in all three ranges. Late Tertiary Basin and Range block faulting converted the landscape into a series of alternating mountains and valleys.

URANIUM FAVORABILITY

Most areas of the Santa Catalina, Rincon, and Tortolita Mountains contain no uranium occurrences. However, significant uranium mineralization is present in the Blue Rock mine area along the east flank of the complex The mine area is currently being actively explored via drilling. Mineralization is concentrated along low-angle fault structures that juxtapose Precambrian crystalline rocks, Paleozoic and Mesozoic sedimentary rocks, and granitic rocks of uncertain age. It is not clear whether these faults are related to Tertiary normal faulting (dislocation?) or Laramide compressional tectonics. Mineralized segments of the faults contain abundant limonite and sporadic purple fluorite. Copper minerals have also been reported in tha area. Autunite and uranophane are evidently the primary uranium minerals. The origin of the mineralization may be hydrothermal, meteoric, or a combination of the two. The Blue Rock Mine area is one of the most favorable areas within the Arizona core complexes. The fault system which contains the Blue Rock Mine extends tens of kilometers in both directions along strike. These extensions should be explored.

The Blue Rock Mine area is more favorable than the rest of the Santa Catalina, Rincon, and Tortolita Mountains. The complex, on the whole possesses very low uranium contents. We have extensively sampled the granites of the complex to evaluate their uranium contents and to document the behavior of uranium during crystallization of three distinct plutonic episodes (Keith and others, 1980). The Late Cretaceous - early Tertiary granodiorites and quartz diorites typically have between 0.5 and 2.5 ppm uranium. They exhibit fairly low radioactivity (slightly less than 100 cps). Eocene muscovite granites of the complex are more "differentiated" rocks, but have lower radioactivity (generally 80 - 100 cps). Uranium and thorium contents of the muscovite granites are both low (generally less than 2 ppm and commonly less than 1 ppm). As discussed in Chapter 5, these granites are also depleted in thorium and other large-ion-lithophile elements. Pegmatitic phases of the muscovite granites have higher uranium contents, but still are well below that expected for granitic pegmatites. Middle Tertiary quartz monzonites (monzogranites) have moderate uranium contents except for the Reef of Rock granite which has an average of approximately 20 ppm uranium for two samples.

Detailed scintillometer traverses from biotite-stable, mylonitic rocks to chloritic breccia reveal little variation between total counts (100-120 cps) of the two rock types Uranium contents of the rocks were evidently not changed by development of the chloritic breccia and overlying dislocation surface.

The presence of important uranium occurrences in the Blue Rock Mine area suggests that the complex has moderate favorability for the discovery of significant uranium reserves. Outside of the Blue Rock Mine area, the complex has low favorability.

URANIUM OCCURRENCES

A-309 - Anomalous radioactivity occurs in Quaternary-Tertiary sediments.

A-316 - Radioactivity occurs in a shear zone in Cretaceous Limestone near a thrust contact between the limestone and Precambrian schist.

A-328 - Radioactivity occurs in a gouge zone in a faulted terrain. Pinal schist is thrust over Cretaceous Bisbee clastic sediments. The thrust dips to the north-east.

A-807 - Radioactivity occurs in granite and schist host rocks which contain many pegmatite bands along with lens of feldspar, muscovite, quartz and garnet.

A-808 - Radioactivity occurs in an epidotized schist below which lies on E-W trending "hematite filled structure" in banded gneiss.

A-810 - A uraniferous shale is found in a homoclinal series of sedimentary rocks striking N55W and dipping 35°N.

A-816- Radioactivity occurs in Pliocene lake bed muds, clays and gravels.

A-822 - Radioactivity occurs in an epidotized E-W trending structure in banded gneiss.

A-828 - Radioactivity occurs in a contact metamorphosed (marbilized) Paleozoic limestone.

A-830 - Radioactivity occurs in a highly silicified and brecciated quartz-pebble conglomerate of probable Tertiary age.

A-835 - Glass vugs in thin beds of tuff which are parts of a series of recent lake bed sediments are anomalously radioactive.

A-840 - Radioactivity occurs in shale lenses in the basal conglomerate of the Oligocene Mineta Formation. Some hydrothermal and structural control is evident.

A-841 - A shear zone dipping to the NE separates Precambrian granite from Cretaceous clastic sediments. The anomalous radioactivity is found in the clastic sediments.

A-842 - A radioactive fracture zone cuts Paleozoic(?) or Cretaceous(?) quartzite overlain by limestone.

A-843 - Radioactive count is found in the Oligocene Mineta Formation and in the underlying Precambrian granite. The contact between the two host rocks is depositional.

A-844 - Uranium mineralization occurs in the Oligocene Mineta Formation.

A-845 - The host rock type is uncertain. A shear zone places "granite against Oligocene Mineta Formation" or "Cretaceous sediments against paleosediments."

PINALENO - SANTA TERESA MOUNTAINS

GEOLOGY

By

Charles F. Kluth

Introduction

The Pinaleno and Santa Teresa Mountains are the easternmost of the metamorphic core complex terranes in Arizona. Together, these mountains make up a rugged fault-block range in the mountain sub-province of the Basin and Range physiographic province of southeastern Arizona. The mountains are located southwest of the Mogollon Rim and the White Mountains-Datil volcanic field which marks the physiographic boundary of the Colorado Plateau Province in that region. Principal works in these two ranges are the mapping of Blacet and Miller (1978), a thesis by Swan (1976), and discussions of the geology by Davis (1980), Rehrig and Reynolds (1980), and Davis and Hardy (this volume).

General Geology

Features associated with metamorphic core complex terranes are found in the northern part of the Pinaleno Mountains and the southern Santa Teresa Mountains. The Pinaleno Mountains are largely composed of undeformed Precambrian (approximately 1.4 b.y.B.P.) gneisses and schists which display north- to east-striking foliation. Along the northeastern margin of the range, the gneisses possess a gently dipping mylonitic foliation and prominant northeast-trending lineation. A sample from this mylonitic zone yields a K-Ar whole-rock date of 28.3 m.y. suggesting a mid-Tertiary thermal event (Rehrig and Reynolds, 1980).

In the area between the Pinaleno and Santa Teresa Mountains, a Precambrian (?) granitic rock becomes cataclastically deformed upwards toward a west-dipping dislocation surface. The dislocation surface is overlain by a thick section of mid-Tertiary volcanic and sedimentary rocks which dip steeply to the southwest (Rehrig and Reynolds, 1980).

To the north, the Santa Teresa Mountains contain granitic and metamorphic rocks which exhibit a gently dipping foliation and northeast-trending lineation. These mylonitic rocks are separated by a synformal (?), low-angle dislocation surface from overlying mid-Tertiary sedimentary and volcanic rocks. Several large mid-Tertiary granitic plutons are exposed in the range (Rehrig and Reynolds, 1980.)

Rock Units

Crystalline Core

P€m - Precambrian metamorphic rocks. This unit includes schistose and gneissic rocks that exhibit a generally steeply dipping foliation. These rocks are locally mylonitic.

P€gc - Precambrian granitic rock. This unit includes undeformed, generally coarse-grained granites which are approximately 1.4 b.y. old. In northeastern parts of the Pinaleno Mountains, this unit includes mylonitically deformed rocks that yield a middle Tertiary cooling age.

Cover

Ts - Tertiary sedimentary rocks. These consist of sandstone, conglomerate and fanglomerate deposited under continental conditions.

Tv - Tertiary volcanic rocks. This unit includes middle Tertiary silicic volcanic rocks that overlie the dislocation surface.

TQs - Late Tertiary - Quaternary surficial deposits. This unit includes alluvial and colluvial sediments, generally unconsolidated, and overlying older rocks unconformably.

Geologic Evolution

The Precambrian history of the Pinaleno-Santa Teresa Mountains is partially recorded in the Precambrian metamorphic rocks which were probably pelitic and silicic sedimentary rocks. These were metamorphosed in Precambrian time (1.7 b.y.B.P.) and intruded by granitic rocks about 1.4 b.y. ago. No Paleozoic or Mesozoic rocks are preserved in this area, but it probably shares a common history as a cratonic shelf with the rest of southeastern Arizona during much of Paleozoic and Mesozoic time. Mid-Tertiary ignimbrites covered the area and coeval (?) thick fanglomerates suggest structural and topographic relief during this time. Finally normal faulting blocked out basins and ranges in the late Tertiary.

URANIUM FAVORABILITY

There are a number of uranium occurrences in the Pinaleno - Santa Teresa mountain range. Many of the occurrences are in veins which cut granitic rocks. Several veins contain hematite and/or fluorite and one vein contains copper sulfides. Other occurrences are associated with Precambrian pegmatites or Tertiary volcanic rocks. Precambrian granites at the south end of the Pinaleno Mountains have high radiometric backgrounds (over 200 cps). Several of the uranium occurrences listed below are located in these granites. Mylonitic rocks along the northeastern flank of the range have lower radiometric signatures (100-120 cps).

The complex has a moderate to low favorability for significant uranium reserves, however, the substantial number of anomalous occurrences warrant further study.

URANIUM OCCURRENCES

A-200 - Radioactivity occurs in a quartz vein in granite.

A-202 - Radioactivity occurs in pegmatite dikes in a Precambrian granite.

A-203 - Radioactivity occurs in a small mineralized fracture in a coarse-grained granite.

A-204 - Radioactivity occurs in a diabase intrusive in Precambrian quartzite.

A-205 - Radioactivity occurs in a quartz vein in a post-Paleozoic granite.

A-207 - Radioactivity occurs in a pegmatite in Precambrian granite.

A-212 - Radioactivity occurs in mineralized en-echelon faults in a Precambrian granite intruded by rhyolite dikes.

A-213 - Radioactivity occurs in quartz veins in an altered granite.

A-215 - Radioactivity occurs in quartz vein in granite.

A-218 - Radioactivity occurs in a pegmatite dike in granite.

A-219 - Radioactivity occurs in a quartz vein in a granite porphyry.

A-220 - Radioactivity occurs within fractures in granite.

SIERRA BLANCA

GEOLOGY

By

Charles F. Kluth

Introduction

Sierra Blanca is located on the Papago Indian Reservation in south-central Arizona, northwest of Sells, Arizona. Sierra Blanca is a low, but rugged generally north-northwest trending range in the Basin and Range Province of southern Arizona. Principal work on this area is mapping by Rytuba and others (1978) and mapping and discussion by Davis (1980).

General Geology

Sierra Blanca is dominantly composed of Mesozoic metasedimentary and metavolcanic rocks in the northern part, and quartz monzonitic augen gneisses in its southern part. The metamorphic rocks are intruded by abundant, undeformed pegmatite dikes. Cataclastic foliation which cuts the metamorphic rocks is arched into a broad north-northwest trending doubly plunging anticlinal flexure. A penetrative lineation contained in these rocks trends generally north-northwest, parallel to the axis of the arch. Overlying the metamorphic rocks on the west side of the arch are deformed, metamorphosed Paleozoic sedimentary rocks. On the southeast side the metamorphic rocks are overlain by Mesozoic metasedimentary rocks. In both the west side and the southeast side the lineated metamorphic rocks are separated from the overlying rocks by a moderate- to low-angle dislocation surface which is marked by a chloritic breccia. These two dislocation surfaces may be parts of a single, once more continuous zone.

Rock Units

Crystalline Core

MZsvm - metamorphosed Mesozoic sedimentary rocks. This unit includes metamorphosed Mesozoic clastic sedimentary rocks and silicic volcanic rocks. It also includes abundant pegmatite dikes.

Tgm - deformed Tertiary (?) granite. This unit includes a foliated quartz monzonite intrusion which contains a penetrative north-northwest penetrative lineation. This unit includes abundant pegmatite dikes and schist septa.

Cover

Pzsm - metamorphosed Paleozoic sedimentary rocks. This unit includes marbles, quartzites and phyllitic schists tentatively correlated to Paleozoic sedimentary rocks to the north and east.

Post-Middle Miocene Units

TQs - Late Tertiary Quaternary surficial deposits. This unit includes Late Tertiary Quaternary alluvial and colluvial sediments which are generally unconsolidated and which overlie older rocks and structures unconformably.

Geologic Evolution

The Precambrian setting of the Sierra Blanca Mountains is uncertain, because few, if any, Precambrian rocks are exposed. During the Paleozoic, the area was probably part of a cratonic shelf accumulating a relatively thin sedimentary section. Mesozoic sedimentary and volcanic rocks probably were deposited in cratonic, volcanic arc. Following deposition of the Mesozoic rocks Tertiary metamorphic and intrusive events affected the area. Finally Basin-Range faulting blocked out the present mountain ranges and basins in late-Tertiary time.

URANIUM FAVORABILITY

One uranium occurrence has been found to the east of the Sierra Blanca (Wachter, 1979). In this occurrence, high total count (average of two selected samples was approximately 1.1% eU_3O_8) is associated with oxidized copper and iron minerals in veins that cut altered andesite. It is probable that the copper, iron, and uranium mineralization is the result of Tertiary hydrothermal fluids. There are similar occurrences of uranium in mountain ranges to the east, but none are actually within the Sierra Blanca complex. The complex is characterized by low to moderate over-all radioactivity (50-150 cps), and is judged to have very low favorability for the discovery of significant uranium reserves.

URANIUM OCCURRENCES

A-804 - Radioactivity occurs in a vein in altered andesite.

A-805 - Radioactivity occurs in a mineralized shear zone in moderately to well altered andesitic rock.

A-825 - Radioactivity occurs in an iron oxide vein in faulted arkosic rocks (Jurassic?) near a granite contact.

A-839 - Radioactivity occurs in a fault zone cutting granite. Most of the anomalous activity is due to elements other than uranium.

NORTH COMOBABI MOUNTAINS

GEOLOGY

By

Charles F. Kluth

Introduction

The North Comobabi Mountains are located approximately 100 km west of Tucson, Arizona. Metamorphic core complex terrane occurs in the southeastern part of this low but rugged block-faulted range in the Basin and Range Province of southern Arizona. Principal work on the North Comobabi area is by Haxel and others (1978, 1980) and Davis (1980).

General Geology

The North Comobabi Mountains are dominantly composed of Jurassic and Cretaceous granitic rocks, silicic volcanics and volcaniclastic sedimentary rocks which are variably metamorphosed. In the southeastern part of the range is an area of Mesozoic metasedimentary and metavolcanic rocks and foliated Cenozoic (?) granitic rocks. These rocks exhibit a moderately northwest-dipping foliation and that contains a generally north-trending penetrative lineation. On their northwest margin the metasediments are separated from overlying Jurassic granitic rocks by a low-angle dislocation surface and a chloritic breccia. The west side of the area is truncated by a high-angle fault that is probably related to Basin and Range block faulting.

Rock Units

Crystalline Core

Mzsvm - Mesozoic metasedimentary and metavolcanic rocks. This unit includes foliated and lineated phyllitic schists whose parent material was sandstones, conglomerates and silicic volcanics.

Tg - foliated Tertiary (?) granite. This unit includes fine- to medium-grained foliated granitic rocks.

Cover

Mzv - Mesozoic volcanic rocks. This unit includes Mesozoic silicic volcanics and associated volcaniclastic sedimentary rocks.

Mzg - Mesozoic granitic rocks. This unit includes Mesozoic granitoid rocks ranging from granite to syenite.

Post-Middle Miocene Units

TQs - Late Tertiary - Quaternary surficial deposits. This unit includes Tertiary and Quaternary alluvial and colluvial sediments, which are variably consolidated and which overlie older rocks and structures unconformably.

Geologic Evolution

The pre-Jurassic geologic evolution of the North Comobabi Mountains is uncertain because rocks older than this are not exposed. This area was the site of intermittant magmatic activity from about early Jurassic into the early Tertiary and may have been part of a diffuse, continental volcanic arc. The area underwent a Mesozoic metamorphic event that affected at least some of the rocks in the area. The metamorphic core complex terrane in the southeast part is probably the result of Tertiary deformation which predated late-Tertiary Basin and Range faulting.

URANIUM FAVORABILITY

There are no occurrences of uranium reported for the Comobabi Mountains or their vicinity. There are also no known occurrences of metallic minerals in the crystalline core of the comples. Rocks of the core generally exhibit low total counts on a gamma-ray scintillometer (50-60 cps). Accordingly, the North Comobabi Mountains have very low favorability for uranium occurrences.

COYOTE MOUNTAINS

GEOLOGY

By

Charles F. Kluth

Introduction

The Coyote Mountains are located about 80 km west-southwest of Tucson, Arizona at the northern end of the Baboquivari Mountains. The Coyote-Baboquivari Mountains are a block faulted range in the southern Arizona Basin-Range province. Principal work on the Coyote Mountains includes Wargo and Kurtz (1967), Davis (1980), and Haxel and others (1980).

General Geology

The Coyote Mountains are mainly composed of undeformed Mesozoic and Cenozoic granite, leucogranite and quartz diorite with septa of Paleozoic sedimentary rocks and abundant pegmatite dikes. At the northern end of the range however, a northeast dipping shell about 500 meters thick of mylonitically deformed rocks display characteristics typical of metamorphic core complexes. This zone is marked by moderate to low-dipping mylonitic foliation and a north-trending penetrative lineation. Mylonitic rocks are separated from overlying mid-Tertiary sedimentary rocks by a moderately dipping dislocation surface which is marked by a chloritic breccia.

Rock Units

Crystalline Core

Pzm - metamorphosed Paleozoic sedimentary rocks. This unit includes quartzitic lower Paleozoic and carbonate middle Paleozoic sedimentary rocks that occur as septa and inclusions in the surrounding granitic rocks. This unit is progressively deformed northward.

Mzg - undeformed Mesozoic granitic rocks. This unit includes Mesozoic granite and quartz diorite with some Cenozoic granite and pegmatite.

Cover

Ts - Tertiary sedimentary rocks. This unit includes variably consolidated, mid-Tertiary volcaniclastic sandstone and mudstone that are involved in the low-angle faulting.

Post-Middle Miocene Units

TQs - Late Tertiary - Quaternary surficial deposits. This unit includes alluvial and colluvial sediments which are generally unconsolidated and which overlie older structures and rocks unconformably.

Geologic Evolution

No Precambrian rocks are exposed in the Coyote Mountains so the pre-Paleozoic history is uncertain. The presence of Paleozoic sedimentary rocks suggests that the area was part of the southern Arizona cratonic platform during that time. The area was intruded by granitic rocks in the Mesozoic and Cenozoic, and was subsequently deformed in the middle(?) Tertiary. Finally, the Coyote Mountains were block-faulted in the late-Tertiary Basin and Range disturbance.

URANIUM FAVORABILITY

Two small occurrences of high radioactivity have been described in the Coyote Mountains. Minor shows of copper and manganese mineralization have also been found in the area, but these are evidently not highly uraniferous. Granites sampled by Marjaniemi nd Basler (1972) in the adjoining Quinlan Mountains have average uranium contents (3 to 4 ppm). An airborne radiometric survey (Texas Instruments, 1979) reveals anomalies located near the dislocation zone on the northeastern margin of the range. The origin of these anomalies is uncertain and should be investigated further. With the possible exception of this anomalous area, the Coyote Mountains probably have very low favorability for uranium occurrences.

URANIUM OCCURRENCES

A-811 - Radioactivity occurs in a biotite gneiss containing pegmatitic zones that trend NE-SW.

A-836 - Radioactivity associated with unaltered fracture zones in N-S trending ridges of granitic gneiss with muscovite.

KUPK HILLS AND ALVAREZ MOUNTAINS

GEOLOGY

By

Charles F. Kluth

Introduction

The Kupk Hills and Alverez Mountains are located near the center of the Papago Indian Reservation, approximately 250 km west-southwest of Tucson, Arizona. Principal work on these two small areas is brief mention in Davis (1980).

General Geology and Rock Units

Both the Kupk Hills and Alvarez Mountains represent small monadnocks projecting to the surface through Late Tertiary Quaternary cover. Both are composed of leucocratic granites which contain a gently dipping foliation and generally north-trending lineation. The foliated rocks were presumably derived from a Phanerozoic plutonic rock of granitic composition. No apparent remnants of dislocation-surfaces or cover rocks are preserved in either area.

Geologic Evolution

The only record of the evolution of the area of the Kupk Hills or Alvarez Mountains is that of a Phanerozoic (?) plutonic event and later metamorphic event. By comparison with surrounding areas, admittedly distant, the area was probably part of a Paleozoic cratonic shelf and Mesozoic magmatic arc terrane. Basin-Range faulting blocked out the present basins and ranges in the late Tertiary.

URANIUM FAVORABILITY

There are no occurrences of uranium reported in the Kupk Hills or Alvarez Mountains. Scintillometry indicates that rocks in both ranges are not anomalous (50-60 cps). Both ranges have very low favorability for the discovery of uranium deposits.

POZO VERDE MOUNTAINS

GEOLOGY

By

Charles F. Kluth

Introduction

The Pozo Verde Mountains are located along the Arizona-Mexico international border at the southern end of the Baboquavari Mountains, southwest of Tucson, Arizona. The Pozo Verde-Baboquavari Mountains are a north-trending, block-faulted range in the Basin and Range Province of southern Arizona. Principal work on the Pozo Verde metamorphic core complex terrane is mapping and discussion by Davis (1980) and Haxel and others (1980).

General Geology

The Pozo Verde Mountains are dominantly composed of foliated quartz monzonitie that contains a lineation which consistantly trends N30E. Foliation within the pluton forms a somewhat sinuous, north-northwest trending, broad arch. The foliation decreases gradually northward toward unlineated pegmatitic and aplitic rocks. Apparently, no remnant of the dislocation surface or cover is preserved in the Pozo Verde Mountains.

Rock Units

Crystalline Core

Tgm - foliated Tertiary muscovite granite. This unit includes foliated rocks derived from Tertiary plutonic rocks of granitic composition. Low to moderately dipping foliation containing a penetrative lineation gradually decreases northward.

Tg - Tertiary granitic rocks. This unit includes Tertiary pegmatitic and aplitic intrusions that locally contain abundant inclusions of Mesozoic schist. Both the pegmatite and aplites are undeformed.

Post-Middle Miocene Units

TQs - Late Tertiary - Quaternary surficial deposits. This unit includes generally unconsolidated alluvial and colluvial sediments which overlie older rocks and structures unconformably.

Geologic Evolution

The geologic evolution of the Pozo Verde Mountains is difficult to reconstruct because so few units are present and because so little work has been done in the area. Inclusion of Mesozoic schists in intrusive rocks suggest that the area underwent a metamorphic event in the Mesozoic but the relation of this area to regions with unmetamorphosed Mesozoic rocks is not clear. The Pozo Verde Mountains were affected by mylonitization before the intrusion of pegmatites and aplites during the Tertiary. Finally Basin-Range faulting blocked out the range in late Tertiary time.

URANIUM FAVORABILITY

The Pozo Verde Mountains contain two reported uranium occurrences. In one occurrence, high radiometric readings (35x background, 0.13 % eU_3O_8) were measured in metasedimentary rocks near dikes and quartz veins. The presence of copper mineralization suggests that uranium and copper may have been deposited together by hydrothermal fluids produced by intrusion of the dikes. There are no occurrences of metallic minerals in the Pozo Verde metamorphic core complex, which indicates that the early Tertiary muscovite granite that comprises most of the complex was deficient in metals, including uranium. The range is characterized by low radioactivity (50-100 cps). Therefore, the Pozo Verde complex is unfavorable for the discovery of significant uranium reserves.

URANIUM OCCURRENCES

A-826 - Radioactivity occurs in fractures and quartz vein that cut a altered granite. Dikes are present.

A-834 - Radioactivity is associated with foliated rocks of uncertain origin.

APPENDIX E

LOCATIONS, LITHOLOGIC DESCRIPTIONS, PETROGRAPHIC INFORMATION AND ANALYTICAL DATA FOR GEOCHEMICAL SAMPLES

Tabulated By

Stephen J. Reynolds, Stanley B. Keith and James F. DuBois

Introduction

This appendix contains the locations, lithologic descriptions, and analytical data for geochemical samples collected during this project by Keith and Reynolds. In addition, it includes a summary of petrographic observations by DuBois on muscovite granites and other plutonic rocks of the Santa Catalina Mountains. Conclusions based on the data contained in this Appendix are discussed in Chapters 4 and 5.

SAMPLING AND ANALYTICAL PROCEDURES

During the course of this project we collected several hundred rock samples in order to characterize the geochemistry of selected Cordilleran metamorphic core complexes. Samples weighing 4 to 10 Kg were collected of plutonic, metamorphic, mylonitic, and altered-mineralized rocks. In general we collected samples at blasted road-cuts with a small sledgehammer, being very careful to get fresh specimens that were representative of the entire rock unit. In mineralized zones, the most highly altered and mineralized lithologies were collected. Samples were placed into labeled cloth sample sacks; mineralized rocks were segregated from other samples. A representative hand specimen was collected for later thin section examination.

Scintillometer readings were measured at each sample locality with a Geometrics 101-A scintillometer (total gamma count). Wherever possible, readings were taken by placing the scintillometer directly on a rock surface which was quasi-planar for at least a meter in all directions; overhangs and corners were carefully aovided.

Major element chemistry of selected samples was determined by Bendix Field Engineering Corporation in Grand Junction (N. Korte - Senior analyst); determinations were done by atomic absorption except for iron and phosphorous which were analyzed by colorimetry.

Minor and major element abundances were determined by inductively coupled plasma source spectrography at the Union Carbide Oak Ridge Gaseous Diffusion Plant. Acid soluable uranium content was analyzed by fluorimetry while total uranium content was determined by delayed-counting neutron activation.

TABLE E-1

BRIEF LITHOLOGIC DESCRIPTIONS OF GEOCHEMICAL SAMPLES

Ruby Mountains, Nevada

155753 - Jurassic(?) granite: medium-grained biotite monzogranite, nonfoliated, anomalous radioactivity.

155754 - Paleozoic calc-silicate: diopside-bearing marble with brown biotite.

155755 - Jurassic(?) granite: tan-colored, medium-grained biotite monzogranite.

155756 - Jurassic(?) granite: medium-grained biotite monzogranite, nonfoliated, anomalous radioactivity.

155757 - Jurassic(?) granite: weakly foliated biotite monzogranite, anomalous radioactivity.

155758 - Jurassic(?) granite: coarse-grained biotite granite, associated with large pegmatites.

155759 - Paleozoic calc-silicate: diopside-bearing marble, highly contorted layering.

155760 - Jurassic(?) granite: medium-grained biotite monzogranite, anomalous radioactivity.

155761 - Jurassic(?) granite: coarse-grained, well-foliated granite, associated with gneiss and pegmatites.

155762 - Granitic gneiss: quartzo-feldspathic gneiss.

155763 - Jurassic(?) granite: unfoliated biotite monzogranite dike which cuts coarse-grained granite, anomalous radioactivity.

155764 - Jurassic(?) granite: coarse-grained, pegmatitic granite with mylonitic fabric.

155765 - Paleozoic(?) quartzite: interlayered quartzite, pegmatite, sillimanite-bearing schist and gneiss.

155766 - Paleozoic(?) quartzite: interlayered quartzite, pegmatitic granite, and gneiss.

155767 - Mesozoic(?) alaskite: garnet-bearing alaskite with well-developed mylonitic fabric.

155768 - Paleozoic(?) quartzite: mylonitic quartzite interlayered with granite and pegmatite.

155769 - Paleozoic(?) quartzite: interlayered quartzite, granite and fine-grained metasedimentary rocks.

155770 - Cretaceous granite: medium-grained two-mica granite, equigranular.

155771 - Cretaceous granite: medium-grained two-mica granite, muscovite less abundant than biotite.

155772 - Cretaceous pegmatite: muscovite- and garnet-bearing pegmatite with graphic texture.

155773 - Tertiary Harrison Pass Granite: biotite monzogranite with large K-feldspar megacrysts.

155774 - Tertiary Harrison Pass Granite: biotite- and hornblende-bearing monzogranite, contains sphene.

Granite Wash Mountains, Arizona

155775 - Late Cretaceous Granite Wash granodiorite: medium-grained, biotite- and hornblende-bearing granodiorite, contains sphene.

155776 - Late Cretaceous Tank Pass granite: medium-grained, equigranular biotite granite.

155777 - Dioritic border phase of Late Cretaceous Granite Wash granodiorite: medium-grained, hornblende-bearing diorite.

155778 - Late Cretaceous Tank Pass granite (aplite): garnet-bearing aplitic dike within Tank Pass granite.

Harquahala Mountains, Arizona

155779 - Socorro Mine mineralization: limonitic gouge zone with copper, lead and molybdenum minerals.

155780 - Socorro Mine mineralization: select sample of above

155781 - Precambrian Socorro granite: coarse-grained granite with large K-feldspar megacrysts.

155782 - Early Tertiary granite: medium-grained alaskitic granite containing muscovite and garnet.

155784 - Early Tertiary granite: medium-grained granite containing large muscovite and minor garnet.

155785 - Early Tertiary pegmatite: coarse-grained, muscovite and garnet-bearing pegmatite.

155786 - Precambrian granite: coarse-grained, porphyritic, biotite-rich granite, mylonitic.

155787 - Precambrian granite: coarse-grained, porphritic granite, mylonitic.

155788 - Tertiary microdiorite: dark-colored, fine- to medium-grained diorite.

Harcuvar Mountains

155789 - Tertiary ash-flow tuff: maroon, trachytic, welded ash-flow tuff.

155790 - Doland Mine mineralization: limonitic zone that contains iron and copper minerals.

155791 - Tertiary microdiorite: microdiorite adjacent to Doland Mine mineralization.

155792 - Late Cretaceous Tank Pass granite: medium-grained, leucocratic biotite granite, foliated.

155793 - Bonanza Mine mineralization: limonitic zone with copper and iron minerals.

155794 - Bonanza Mine mineralization: same as above.

155795 - Mica schist: biotite-muscovite schist interlayered with quartzo-feldspathic gneiss.

155796 - Mica schist: similar to above.

155797 - Granitic gneiss: compositionally layered granitic gneiss.

155798 - Early Tertiary(?) leucogranite: muscovite-garnet leucogranite with minor biotite.

155799 - Gneiss, quartzo-feldspathic, biotite-bearing gneiss.

155800 - Late Cretaceous Tank Pass granite: foliated leucocratic granite with minor biotite.

155801 - Gneiss: quartzo-feldspathic gneiss, biotitic with some mylonitic fabric.

155802 - Pegmatite: undeformed quartz-feldspar pegmatite.

Buckskin Mountains, Arizona

155803 - Tertiary chloritic breccia: chloritized, brecciated, gneiss which contains relict mylonitic fabric.

155804 - Tertiary dislocation zone: sample of gouge zone at dislocation surface between underlying chloritic breccia and overlying Tertiary sedimentary rocks.

155805 - Tertiary chloritic breccia: brecciated, chloritic gneiss with hematite and limonite.

155806 - Alamo mineralization: limonitic zone at the base of Paleozoic metacarbonate rocks.

155807 - Gneiss: quartzo-feldspathic gneiss with well developed mylonitic fabric.

155808 - Granitic gneiss: granodioritic gneiss with little compositional banding.

155809 - Gneiss: compositionally layered quartzo-feldspathic gneiss, micaceous schist, and granitoid rocks.

Eastern Harcuvar Mountains, Arizona

155810 - Cretaceous(?) granite: biotite granite with well-developed mylonitic fabric.

155811 - Precambrian(?) amphibolite: plagioclase-, biotite- and hornblende-bearing amphibolite with mylonitic fabric.

155812 - Granitic gneiss: quartzo-geldspathic gneiss with well-defined compositional banding and mylonitic fabric.

Snake Range, Nevada

155813 - Granite: slightly porphyritic granite with muscovite and garnet, nonfoliated.

155814 - Granite: chloritized granite exposed beneath Snake Range décollement, rock has muscovite and biotite.

Kern Mountains, Nevada

155815 - Late Cretaceous-early Tertiary Tungstonia Granite: Coarse-grained, porphyritic granite with biotite and very large muscovites.

155816 - Tertiary Skinner Canyon Granite: leucocratic granite with sparse biotite, highly jointed.

Santa Catalina Mountains, Arizona

155817 - Tertiary pegmatite in forerange banded gneiss: muscovite pegmatite with minor hematite, interlayered with augen gneiss.

155818 - Tertiary pegmatite in forerange banded gneiss: foliated pegmatite with minor muscovite and hematite.

155819 - Augen gneiss: biotite-rich, mylonitic augen gneiss, derived from Precambrian Oracle Granite.

155820 - Tertiary(?) granodiorite: medium-grained, foliated biotite granodiorite.

155821 - Augen gneiss: biotite-rich, coarse-grained augen gneiss with mylonitic fabric.

155822 - Augen gneiss: same as above.

155823 - Granitic gneiss: medium-grained biotite-gearing, granodioritic gneiss.

155824 - Tertiary pegmatite in forerange banded gneiss: coarse-grained, muscovite- and garnet-bearing pegmatite with a mylonitic fabric.

155825 - Tertiary pegmatite in forerange banded gneiss: foliated muscovite-and garnet-bearing pegmatite.

155826 - Tertiary(?) granodiorite: medium-grained foliated biotite granodiorite.

155827 - Augen Gneiss: coarse-grained, biotitic augen gneiss, contains a well-developed mylonitic fabric.

155828 - Tertiary pegmatite in forerange banded gneiss: two-mica, garnet pegmatite.

155829 - Tertiary granite: medium-grained biotite granite.

155830 - Quartz diorite: epidote-bearing quartz diorite to granodiorite , probably equivalent to Leatherwood Quartz diorite (Late Cretaceous).

155831 - Tertiary pegmatite in forerange banded gneiss: garnet-bearing, pegmatitic muscovite granite.

155833 - Early Tertiary Wilderness granite: biotite- and garnet-bearing granite with minor muscovite, mylonitic.

155834 - Early Tertiary Wilderness granite: same as above.

155835 - Precambrian Oracle Granite: coarse-grained biotite granite, porphyritic.

155836 - Early Tertiary Wilderness granite: medium-grained, foliated biotite granite, mylonitic.

155837 - Early Tertiary Wilderness granite: same as above except minor muscovite.

155838 - Early Tertiary Wilderness granite: same as above.

155839 - Early Tertiary Wilderness granite: muscovite- and biotite bearing granite.

155840 - Early Tertiary Wilderness granite: medium-grained equigranular two-mica granite.

155841 - Mylonitic schist: biotite-rich mylonitic schist that contains muscovite which replaces the biotite, probably derived from Precambrian Oracle Granite.

155842 - Pegmatite in early Tertiary Wilderness granite: muscovite-garnet pegmatite, probably cogenetic with enclosing muscovite granite.

155843 - Precambrian Oracle Granite: coarse-grained, porphyritic biotite granite, weakly deformed.

155844 - Precambrian Oracle Granite from near type section at Oracle, Arizona (north of Santa Cataline Mountains): biotite- and hornblende-bearing with large, pink rapakivi feldspars. Rock is undeformed and very fresh.

155845 - Early Tertiary Wilderness granite: foliated, medium-grained two-mica granite with abundant garnet.

155846 - Early Tertiary Wilderness granite: same as above.

155847 - Early Tertiary Wilderness granite: similar to above.

155848 - Early Tertiary Wilderness granite: garnet-bearing two-mica granite, very weakly foliated, collected near Hitchcock picnic area.

155849 - Pegmatite in Early Tertiary Wilderness granite: garnet- and muscovite-bearing pegmatite.

155850 - Early Tertiary Wilderness Granite: foliated two-mica granite, garnet-bearing, collected near Windy Point Vista.

155851 - Pegmatite in Early Tertiary Wilderness granite: foliated muscovite-garnet pegmatite from same area as sample 155850.

155852 - Early Tertiary Wilderness granite: weakly foliated medium-grained biotite granite with only minor muscovite and garnet.

155853 - Early Tertiary Wilderness granite: weakly foliated two-mica granite, trace of garnet, collected near San Pedro Vista.

155854 - Early Tertiary Wilderness granite: unfoliated tow-mica granite with minor garnet.

155855 - Pegmatite in early Tertiary Wilderness granite: weakly foliated pegmatite that contains muscovite and garnet.

155856 - Early Tertiary Wilderness granite: foliated, medium-grained, two-mica granite with a trace of garnet.

155857 - Middle Tertiary Reef of Rock granite: medium-grained biotite granite, undeformed.

155858 - Middle Tertiary Reef of Rock granite: same as above.

155859 - Middle Tertiary Reef of Rock granite: same as above.

155860 - Precambrian quartzite: muscovite-bearing arkosic quartzite, derived from Apache Group quartzites.

155861 - Precambrian schist: quartz-feldspar-muscovite schist, derived from Apache Group Rocks.

155863 - Tertiary(?) dike: north-trending rhyolite dike.

155864 - Late Cretaceous Leatherwood quartz diorite: foliated, epidote-sphene-bearing biotite quartz diorite.

155865 - Early Tertiary aplite: garnet-bearing aplite cutting Leatherwood quartz diorite.

155866 - Early Tertiary pegmatite: garnet-bearing pegmatite with phengitic(?) muscovite, part of Lemmon Rock leucogranite.

155868 - Early Tertiary garnet schlieren: garnet-rich bands within a vertically layered muscovite pegmatite.

155869 - Late Cretaceous Leatherwood quartz diorite: similar to sample 155864.

155869 - Late Cretaceous Leatherwood quartz diorite: similar to sample 155864.

155870 - Early Tertiary garnet schlieren: similar to sample 155868, except more garnet.

Further descriptions of Santa Catalina Mountains samples are found beginning with sample number 155914.

Tortolita Mountains, Arizona

155781 - Late Cretaceous Chirreon Wash granodiorite: medium grained dioritic border phase.

155872 - Early Tertiary Derrio Canyon granite: muscovite- and garnet-bearing granite, pegmatitic phase.

155873 - Late Cretaceous Chirreon Wash granodiorite: medium-grained, biotite-rich granodiorite that contains hornblende, epidote and sphene.

155874 - Late Cretaceous Chirreon Wash granodiorite: same as above.

155875 - Late Cretaceous Chirreon Wash granodiorite: same as above except mylonitic.

155876 - Late Cretaceous Chirreon Wash granodiorite: same as ab ove, mylonitic.

155877 - Early Tertiary Derrio Canyon granite: pegmatitic and aplitic phase of muscovite-bearing granite, garnetiferous.

155878 - Late Cretaceous Chirreon Wash granodiorite: same as sample 155873 except weakly mylonitic.

155879 - Inclusion in cataline quartz monzonite: biotite-rich inclusion, probably derived from Chirreon Wash pluton .

155880 - Middle Tertiary Catalina Quartz monzonite: coarst to medium-grained biotite quartz monzonite, sphene- and hornblende-bearing, weakly foliated.

155881 - Middle Tertiary Catalina quartz monzonite: same as above.

155882 - Middle Tertiary Catalina quartz monzonite: same as above.

155883 - Middle Tertiary granitic dike: dike cuts Catalina quartz monzonite, probably related to Tortolita pluton.

155884 - Inclusion in Tortolita quartz monzonite: mafic, biotite-rich inclusion, probably derived from Chirreon Wash pluton.

155885 - Middle Tertiary Tortolita quartz monzonite: medium-grained, equigranular biotite quartz monzonite.

155886 - Aplite in Middle Tertiary Tortolita quartz monzonite: fine-grained, leucocratic aplite dike.

155887 - Middle Tertiary Tortolita quartz monzonite: medium-grained, equigranular biotite quartz monzonite.

155888 - Middle Tertiary Tortolita quartz monzonite: same as above except mylonitic.

155889 - Precambrian Oracle Granite(?): strongly mylonitic biotitic granite which may have been Oracle Granite.

155890 - Precambrian Oracle Granite: weakly mylonitic Oracle Granite, porphyritic, chloritic and coarse-grained.

155891 - Precambrian Oracle Granite: mylonitic biotite-rich granite, contains some muscovite (due to mylonitization).

166892 - Precambrian Oracle Granite: same as above.

155893 - Precambrian Oracle Granite: same as above.

155894 - Precambrian Pinal Schist: schistose band exposed north of Chirreon Wash granodiorite.

155895 - Precambrian Pinal Schist: same as above.

155896 - Late Cretaceous Chirreon Wash granodiorite: mylonitic biotite-rich granodiorite, contains hornblende, epidote and sphene.

155897 - Late Cretaceous Chirreon Wash granodiorite: same as above except weakly mylonitic.

155898 - Precambrian Oracle Granite: coarse-grained, porphyritic granite with some chlorite.

155899 - Precambrian Oracle Granite: mylonitic granite with muscovite (formed during mylonitization).

155900 - Precambrian Pinal Schist: schistose band exposed north of Chirreon Wash pluton.

155901 - Precambrian Oracle Granite: mylonitic granite with minor muscovite (formed during mylonitization).

155902 - Precambrian Pinal Schist: mica schist.

155904 - Middle Tertiary Tortolita quartz monzonite: medium grained biotite quartz monzonite.

155905 - Precambrian Oracle Granite: mylonitic granite that occurs within middle Tertiary Catalina quartz monzonite.

155906 - Precambrian Pinal Schist: schistose band exposed south of the Chirreon pluton.

155907 - Early Tertiary Derrio Canyon granite: mylonitic, muscovite-garnet leucogranite.

155908 - Middle Tertiary Tortolita quartz monzonite: mylonitic biotite granite.

155909 - Middle Tertiray Tortolita quartz monzonite: mylonitic biotite granite.

155910 - Early Tertiary Derrio Canyon granite: mylonitic muscovite- and garnet-bearing leucocratic granite.

155911 - Early Tertiary Derrio Canyon granite: mylonitic muscovite- garnet pegmatite.

155912 - Early Tertiary Derrio Canyon granite: weakly mylonitic muscovite- and garnet-bearing granite.

155913 - Tertiary diorite: dark-colored diorite that intrudes Chirreon Wash pluton.

155922 - Inclusion in Catalina quartz monzonite: dioritic with K-feldspar megacrysts of probable metasomatic origin.

Santa Catalina Mountains, Arizona (continued)

155914 - Precambrian(?) diorite: foliated riorite of uncertain age.

155915 - Precambrian Oracle Granite: mylonitic granite, biotite-rich.

155916 - Precambrian Oracle Granite: same as above.

155917 - Late Cretaceous Leatherwood quartz diorite(?): mylonitic diorite of uncertain age.

155918 - Early Tertiary Wilderness granite: medium-grained, biotite granite, mylonitic.

155919 - Early Tertiary Wilderness granite: two-mica granite with garnet.

155920 - Early Tertiary Wilderness granite: same as above.

155921 - Late Cretaceous Leatherwood quartz diorite: biotite- and epidote-bearing quartz diorite.

155923 - Early Tertiary Granodiorite: unfoliated biotite granodiorite, magnetite-bearing.

155924 - Blue Rock Mine mineralization: limonitic dump material near Blue Rock Mine, anomalous radioactivity.

155925 - Blue Rock Mine mineralization: same as above.

155926 - Blue Rock Mine mineralization: select sample of limonitic shear zone with purple fluorite and possible meta-autunite anomalous radioactivity.

Galiuro Mountains, Arizona

155903 - Late Cretaceous Williamson Canyon Volcanics: andesite.

TABLE E-2

MAJOR ELEMENT ANALYSES

	SiO_2	Al_2O_3	K_2O	CaO	Fe_2O_3	FeO	MgO	Na_2O	P_2O_5
155820	73.82	15.3	4.40	1.67	.74	.60	.28	3.78	.03
155823	76.09	13.8	4.82	1.38	.16	.46	.18	3.44	.03
155824	77.47	15.0	1.98	1.50	.06	.15	.04	5.62	.01
155825	74.27	14.6	4.25	.37	.22	.11	.04	2.01	.01
155827	70.20	14.0	2.61	2.18	1.90	2.92	1.11	3.45	.32
155828	71.86	15.3	7.41	.69	.27	.13	.08	4.03	.01
155829	75.60	14.6	5.48	1.28	.27	.31	.14	2.89	.03
155830	64.43	15.2	2.89	2.98	1.18	2.10	1.46	3.41	.15
155831	73.28	14.7	2.30	1.42	.32	.10	.04	5.46	.01
155831	70.63	14.2	4.34	1.49	.67	.18	.09	3.72	.01
155834	71.98	13.6	3.46	1.52	.31	.22	.11	3.96	.01
155838	74.38	15.4	3.92	1.50	.75	.51	.23	3.54	.05
155839	74.10	14.0	3.47	1.10	.52	.21	.12	3.45	.03
155840	75.20	15.1	2.86	1.59	.48	.37	.18	4.39	.03
155842	76.11	14.1	4.13	.55	.23	.18	.07	2.31	.05
155843	70.20	12.0	4.55	.85	.72	1.50	.82	2.17	.17
155845	76.40	14.7	4.10	.96	.25	.24	.08	3.33	.04
155847	74.04	14.9	3.54	1.21	.48	.35	.15	3.86	.03
155848	76.41	14.6	3.64	1.15	.43	.32	.12	3.70	.03
155849	74.91	15.4	4.54	.55	.28	.12	.06	3.77	.02
155851	77.90	14.5	3.65	.61	.12	.16	.04	4.75	.03
155852	75.20	14.4	3.63	1.05	.46	.25	.14	4.19	.03
155854	72.92	14.5	3.42	1.23	.51	.40	.19	4.12	.04
155856	72.06	15.4	3.39	1.46	.81	.75	.41	4.36	.08
155866	77.95	11.8	4.19	.47	-	-	.06	3.31	.12
155870	70.63	13.5	1.92	.25	1.51	1.39	.17	2.08	.03
155871	55.39	17.7	1.55	8.30	4.82	4.60	5.40	3.31	.27
155874	68.76	15.4	3.53	2.71	1.73	1.53	.24	3.73	.13
155876	63.41	16.2	2.79	4.28	2.92	2.54	2.30	3.36	.15
155877	74.52	14.3	3.23	1.89	.52	.47	.18	4.86	.03
155878	68.94	15.6	3.40	3.48	2.63	2.34	2.20	3.52	.18
155880	68.51	14.4	4.31	2.64	2.05	1.85	1.35	3.73	.24
155881	63.35	17.1	3.49	3.11	2.15	2.44	1.78	3.86	.37
155882	61.92	17.1	4.11	3.42	1.98	2.78	2.11	4.03	.35
155885	75.20	14.6	2.97	1.18	.70	.71	.43	2.87	.06
155886	76.96	13.1	4.28	.52	.33	.24	.08	3.94	.04
155887	73.11	14.0	4.26	1.41	.90	.73	.50	3.45	.08
155888	77.27	14.4	4.49	1.48	1.22	.65	.38	3.38	.03
155889	76.40	12.4	3.03	1.88	1.48	1.49	.76	2.68	.21
155890	74.75	12.5	3.96	1.32	1.94	1.07	.82	2.25	.08
155891	71.69	15.6	1.99	.63	1.12	.41	.48	3.64	.09
155893	70.67	15.5	2.32	1.16	1.66	.53	.68	3.79	.11
155895	71.30	13.8	4.09	.84	3.23	1.34	.93	.46	.07
155898	68.47	13.7	3.92	2.08	3.93	2.11	1.33	2.25	.27
155899	74.05	13.3	4.15	1.47	2.75	.82	.71	2.39	.13

	SiO_2	Al_2O_3	K_2O	CaO	Fe_2O_3	FeO	MgO	Na_2O	P_2O_5
155901	72.43	13.5	3.81	1.90	3.04	.56	.71	3.24	.15
155902	66.62	17.5	3.68	.72	5.01	1.47	1.59	1.83	.12
155906	84.73	7.5	2.20	.69	2.16	.95	.44	1.27	.08
155912	72.17	14.5	4.23	1.29	.73	.68	.27	3.20	.06
155923	64.88	19.6	2.09	3.14	.81	1.42	.59	5.61	.14

Table 3. Uranium and Emission Spectrographic Geochemical Analyses

METAMORPHIC CCRE CCMPLEXES

PAGE 1 SECTION 1 OF 3

OR SAMPLE NUMBER	D. O. E. SAMPLE ST LAT	LONG	NUMBER L TY REP	U (PPM)	U-NT (PFM)	U/TJ	AG (PPM)	AL (%)	B (PPM)	BA (PPM)	BE (PPM)	CA (%)	CO (PPM)	CR (PPM)
155753	40-40.601	-115.378	-3-92-	6.18	8.90	0.69	<2	7.12	<10	1187	4	0.97	<4	5
155754	40-40.592	-115.381	-3-92-	0.81	1.10	0.74	<2	3.24	<10	149	1	26.87	4	30
155755	40-40.594	-115.383	-3-92-	0.46	1.00	0.46	<2	7.76	<10	631	1	0.92	<4	3
155756	40-40.602	-115.378	-3-92-	7.66	10.70	0.72	<2	7.20	<10	1103	2	0.89	<4	5
155757	40-40.616	-115.368	-3-92-	6.81	9.90	0.69	<2	7.03	<10	1085	2	0.96	<4	5
155758	40-40.600	-115.379	-3-92-	1.42	2.40	0.59	<2	7.62	<10	542	2	0.58	<4	2
155759	40-40.614	-115.380	-3-92-	1.46	1.40	1.04	<2	4.35	<10	94	1	25.74	6	38
155760	40-40.617	-115.378	-3-92-	17.14	13.80	1.24	<2	7.40	<10	1066	3	0.91	<4	3
155761	40-40.633	-115.369	-3-92-	0.71	0.50	1.42	<2	7.24	<10	696	<1	0.48	<4	2
155762	40-40.633	-115.369	-3-92-	0.71	1.10	0.65	<2	7.07	<10	311	1	1.00	<4	5
155763	40-40.646	-115.405	-3-92-	2.01	4.00	0.50	<2	7.47	<10	1715	2	1.32	<4	9
155764	40-40.658	-115.425	-3-92-	<0.25	0.20	0.63	<2	7.05	<10	5317	<1	0.64	<4	2
155765	40-40.664	-115.440	-3-92-	0.63	1.20	0.53	<2	1.19	<10	93	1	<0.05	<4	18
155766	40-40.661	-115.436	-3-92-	1.69	2.10	0.80	<2	8.08	<10	2732	1	2.39	6	4
155767	40-40.690	-115.474	-3-92-	1.20	1.60	0.75	<2	6.42	<10	916	1	0.66	<4	2
155768	40-40.855	-115.230	-3-92-	1.04	1.30	0.80	<2	2.62	<10	619	<1	0.35	<4	28
155769	40-40.861	-115.235	-3-92-	0.54	1.10	0.49	<2	6.53	<10	666	2	1.31	<4	3
155770	40-40.410	-115.435	-3-92-	4.50	5.40	0.83	<2	7.01	<10	334	9	0.66	<4	3
155771	40-40.402	-115.430	-3-92-	2.21	4.30	0.51	<2	7.09	<10	608	8	0.71	<4	3
155772	40-40.396	-115.452	-3-92-	1.51	2.00	0.75	<2	7.41	<10	17	4	0.44	<4	2
155773	40-40.316	-115.485	-3-92-	5.43	9.20	0.59	<2	6.91	<10	544	3	1.42	<4	4
155774	40-40.325	-115.516	-3-92-	3.00	5.30	0.57	<2	7.98	<10	1027	3	2.35	4	8
155775	40-33.752	-113.670	-3-92-	4.46	4.50	0.99	<2	7.28	<10	933	2	2.48	9	18
155776	40-33.845	-113.700	-3-92-	1.51	3.00	0.50	<2	6.98	<10	875	2	1.03	<4	5
155777	40-33.831	-113.684	-3-92-	1.35	1.70	0.79	<2	7.89	<10	1109	1	3.82	18	18
155778	40-33.832	-113.684	-3-92-	18.82	20.20	0.93	<2	6.72	<10	78	7	0.36	<4	3
155779	40-33.745	-113.470	-3-92-	1.25	1.50	0.83	2	2.02	<10	1444	1	18.96	6	16
155780	40-33.745	-113.470	-3-92-	6.89	6.70	1.03	337	0.38	<10	25	1	7.87	7	6
155781	40-33.729	-113.488	-3-92-	9.58	9.60	1.00	<2	6.42	<10	621	4	0.51	<4	4
155782	40-33.846	-113.342	-3-92-	0.63	0.80	0.79	<2	7.25	<10	527	2	0.78	<4	3
155784	40-33.846	-113.342	-3-92-	0.90	2.20	0.41	<2	7.93	<10	765	2	0.72	<4	3
155785	40-33.846	-113.342	-3-92-	0.90	1.80	0.50	<2	8.09	<10	863	2	0.62	<4	2
155786	40-33.856	-113.351	-3-92-	1.77	3.20	0.55	<2	8.19	<10	1752	3	2.28	8	11
155787	40-33.856	-113.351	-3-92-	2.39	3.70	0.65	<2	7.10	<10	1718	2	1.60	6	10
155788	40-33.856	-113.351	-3-92-	<0.25	1.10	0.11	<2	8.91	<10	1602	1	5.49	25	70
155789	40-34.077	-113.239	-3-92-	2.53	3.70	0.68	<2	5.96	26	4975	1	0.22	<4	5
155790	40-33.895	-113.632	-3-92-	13.04	13.20	0.99	<2	4.14	<10	332	2	2.61	14	300
155791	40-33.895	-113.632	-3-92-	0.59	0.90	0.66	<2	8.39	<10	955	1	7.30	27	125
155792	40-33.895	-113.632	-3-92-	0.35	1.00	0.35	<2	7.37	<10	1164	2	0.86	<4	3
155793	40-33.929	-113.587	-3-92-	22.97	18.20	1.26	<2	2.74	<10	368	1	8.45	22	165
155794	40-33.929	-113.587	-3-92-	21.74	22.00	0.99	<2	3.30	10	323	1	0.47	15	89
155795	40-33.992	-113.574	-3-92-	0.50	3.10	0.16	<2	6.78	<10	1722	1	0.41	16	195
155796	40-33.992	-113.574	-3-92-	1.15	2.20	0.52	<2	8.49	<10	1241	1	0.40	14	116
155797	40-33.992	-113.574	-3-92-	0.92	1.54	0.60	<2	6.85	<10	1643	1	0.84	<4	3
155798	40-33.992	-113.574	-3-92-	<0.25	0.24	0.52	<2	6.52	<10	712	1	0.59	<4	2
155799	40-34.023	-113.519	-3-92-	6.21	9.50	0.65	<2	7.07	<10	818	2	1.72	5	3
155800	40-34.023	-113.519	-3-92-	<0.25	0.50	0.25	<2	7.99	<10	2159	1	1.31	<4	2
155801	40-34.021	-113.511	-3-92-	2.48	5.00	0.50	<2	6.41	<10	1249	2	1.46	<4	3
155802	40-34.021	-113.511	-3-92-	<0.25	0.40	0.31	<2	7.70	<10	552	1	0.48	<4	2
155803	40-34.179	-113.465	-3-92-	1.29	2.50	0.52	<2	8.45	<10	940	2	4.44	20	31
155804	40-34.227	-113.576	-3-92-	2.76	4.00	0.69	<2	6.40	25	1463	4	3.19	13	84
155805	40-34.227	-113.576	-3-92-	1.59	2.30	0.69	<2	6.92	<10	2381	1	1.72	4	31
155806	40-34.226	-113.593	-3-92-	15.19	15.50	0.98	<2	4.30	22	176	2	13.61	29	45
155807	40-34.229	-113.605	-3-92-	0.71	1.30	0.55	<2	7.49	<10	1607	1	0.99	<4	4
155808	40-34.229	-113.605	-3-92-	1.13	1.00	1.13	<2	7.85	<10	1964	1	0.97	<4	3

OR SAMPLE NUMBER	CU (PPM)	FE (%)	LI (PPM)	MG (%)	MN (PPM)	MO (PPM)	NA (%)	NB (PPM)	NI (PPM)	P (PPM)	SC (PPM)	TH (PPM)	TI (PPM)	V (PPM)	Y (PPM)
155753	2	1.48	82	0.20	202	<4	2.77	22	4	373	2	39	1193	11	9
155754	<2	1.68	49	2.37	279	<4	0.41	9	13	171	5	3	1412	29	8
155755	<2	0.59	37	0.13	48	<4	2.20	4	<2	707	4	6	906	<2	5
155756	2	1.56	36	0.22	195	<4	2.51	21	2	363	2	54	1272	12	11
155757	3	1.61	30	0.20	181	<4	2.52	28	3	323	3	60	1361	13	13
155758	3	0.68	42	0.12	112	<4	2.45	9	<2	377	5	8	946	<2	3
155759	2	2.11	23	2.23	372	<4	0.45	10	18	180	5	3	1863	38	8
155760	2	1.41	29	0.18	181	<4	3.03	24	2	363	2	70	1235	11	16
155761	<2	0.53	42	0.13	27	<4	1.92	<4	<2	177	5	3	1004	<2	1
155762	<2	0.76	42	0.18	69	<4	2.50	4	<2	163	5	9	1131	2	2
155763	4	2.54	30	0.40	289	<4	2.67	19	6	763	4	58	3012	34	24
155764	<2	0.66	23	0.14	48	<4	2.05	<4	<2	245	6	<2	1137	2	1
155765	4	0.48	23	0.12	73	<4	0.15	<4	4	40	1	<2	577	33	1
155766	7	3.38	27	0.81	542	<4	2.51	10	6	1160	6	28	4208	65	17
155767	3	0.59	19	0.07	217	<4	2.67	6	2	296	2	4	385	<2	5
155768	6	1.36	17	0.25	90	<4	0.36	5	8	160	3	12	1651	21	5
155769	2	0.12	8	<0.05	25	<4	4.25	<4	2	165	1	7	108	2	2
155770	3	0.63	60	0.10	253	<4	3.39	30	<2	1112	2	6	610	3	10
155771	6	0.86	88	0.14	216	<4	3.16	34	3	559	1	14	949	7	7
155772	6	0.44	40	<0.05	374	<4	3.97	12	<2	296	<1	<2	46	<2	6
155773	51	1.51	66	0.34	417	<4	2.23	15	3	391	3	25	1942	22	12
155774	2	2.84	49	0.71	548	<4	2.61	21	3	820	6	23	4035	48	19
155775	25	2.76	20	1.13	628	<4	2.42	5	15	717	7	7	2696	80	12
155776	22	1.62	22	0.27	332	<4	3.14	10	4	783	2	2	1510	26	5
155777	64	5.37	29	2.15	833	<4	2.41	<4	18	1167	13	7	5186	165	16
155778	4	0.30	2	<0.05	873	<4	3.22	61	<2	59	6	19	151	<2	18
155779	71	1.02	17	4.94	1035	4	0.28	7	15	342	3	7	929	24	10
155780	40981	8.81	8	3.34	797	441	<0.05	<4	14	<5	1	<2	18	<2	9
155781	12	1.71	17	0.26	469	<4	1.95	18	3	534	5	38	1630	16	28
155782	8	0.30	3	0.05	914	<4	3.30	7	<2	193	3	<2	143	2	18
155784	<2	0.43	4	0.07	245	<4	3.06	18	<2	174	5	9	377	6	8
155785	2	0.42	4	0.07	73	<4	3.25	17	<2	120	5	<2	399	5	5
155786	21	4.57	67	0.99	860	<4	2.66	11	8	2484	13	4	5921	81	32
155787	5	3.99	44	0.87	907	<4	2.09	15	7	2022	12	4	6119	64	38
155788	46	6.21	19	2.95	880	<4	3.19	<4	56	3102	18	<2	9082	205	19
155789	6	1.12	35	0.05	564	<4	0.16	14	5	264	1	14	1219	12	16
155790	6219	8.50	51	0.37	1686	8	<0.05	<4	80	2233	10	<2	1349	142	8
155791	50	5.89	25	3.60	1025	<4	2.39	<4	66	1788	27	<2	6662	192	18
155792	38	0.80	9	0.12	178	<4	3.37	7	<2	224	2	3	826	14	3
155793	9884	4.63	25	1.59	1428	<4	0.45	<4	96	1247	7	3	1451	131	9
155794	45685	6.80	19	0.30	1110	<4	0.27	<4	48	296	4	<2	528	91	3
155795	<2	5.43	19	1.18	672	<4	0.63	7	82	233	16	25	5553	114	16
155796	7	5.24	13	1.08	679	<4	0.83	5	36	177	14	13	5073	105	17
155797	20	1.26	4	0.18	138	<4	2.44	<4	2	318	2	14	1183	13	7
155798	5	0.46	2	<0.05	69	<4	2.56	<4	2	49	<1	<2	188	4	1
155799	25	2.23	10	0.63	454	<4	2.37	13	4	631	7	30	2333	47	31
155800	2	0.58	6	0.13	118	4	2.91	<4	3	241	1	2	508	8	2
155801	14	2.55	6	0.43	465	<4	1.77	21	3	1318	8	10	3655	31	42
155802	4	0.50	1	<0.05	91	<4	3.92	<4	2	42	2	<2	94	5	4
155803	100	5.39	27	2.06	1110	5	2.74	8	27	1871	14	15	5610	167	20
155804	102	2.72	72	1.01	513	11	0.20	9	30	1080	11	23	2215	77	24
155805	21	5.20	57	2.10	1519	<4	0.76	5	17	1185	13	6	3312	98	29
155806	88	14.43	49	0.73	432	7	<0.05	46	14	330	8	8	2583	207	23
155807	14	1.06	4	0.20	138	<4	2.59	<4	3	276	1	3	1163	22	3
155808	33	1.02	6	0.21	107	<4	2.37	<4	3	360	1	<2	1324	22	1

METAMORPHIC CORE COMPLEXES

OR SAMPLE NUMBER	ZN (PPM)	ZR (PPM)	K (%)	SR (PPM)	CE (PPM)	TGAM (CPS)	SITE	S-GC
155753	77	19	3.70	116	88	19800	0001	JG
155754	52	<2	0.72	847	19	6600	0002	DCM
155755	27	<2	3.55	228	33	9600	0003	JG
155756	79	19	4.24	118	125	19800	0004	JG
155757	75	25	3.98	107	153	19800	0005	JG
155758	32	<2	3.49	159	25	9600	0006	JG
155759	77	2	0.15	819	31	6600	0007	DCM
155760	70	17	4.34	109	138	27000	0008	JG
155761	21	<2	5.08	224	19	9000	0009	JG
155762	27	<2	3.23	164	32	9000	0010	JG
155763	94	8	3.94	184	400	18000	0011	JG
155764	27	<2	4.76	572	12	6000	0012	JG
155765	14	<2	0.85	7	<10	6000	0013	CZQ
155766	79	2	3.07	432	139	9000	0014	JG
155767	24	<2	3.79	217	23	6300	0015	MZQM
155768	28	<2	1.51	84	58	6000	0016	CZQ
155769	4	<2	1.70	294	30	7500	0017	CZQ
155770	40	3	4.18	115	32	8400	0018	KG
155771	51	4	3.98	170	61	7200	0019	KG
155772	37	2	3.53	25	<10	6000	0020	KG
155773	61	13	2.68	245	56	12000	0021	THP
155774	88	5	2.23	430	100	7800	0022	THP
155775	80	6	2.34	537	44	6000	0023	KGD
155776	70	3	2.63	375	35	6600	0024	KG
155777	109	9	1.52	682	35	3600	0025	KD
155778	34	16	2.88	37	13	6000	0026	KA
155779	331	13	0.90	128	29	6000	0027	SDCO
155780	4582	<2	<0.02	105	<10	6000	0028	SDCO
155781	71	28	3.45	96	94	6000	0029	PCG
155782	8	2	2.86	222	10	4800	0030	TMG
155784	14	2	3.20	236	10	4800	0031	TMG
155785	13	<2	3.88	236	<10	4800	0032	TMG
155786	114	5	3.24	334	104	6000	0033	PCG
155787	101	<2	2.83	265	123	6000	0034	PCG
155788	81	53	1.03	1095	86	5400	0035	TMD
155789	41	83	6.03	45	63	8400	0036	TT
155790	36	4	2.08	109	69	10800	0037	DOLD
155791	81	70	0.64	787	57	5400	0038	TMD
155792	37	<2	3.37	377	28	6000	0039	KG
155793	64	3	0.64	231	70		0040	BDND
155794	156	<2	2.55	81	25		0041	BDND
155795	134	2	4.35	220	152	10200	0042	MMS
155796	96	<2	4.15	105	81	8400	0043	MMS
155797	21	<2	3.98	320	69	7800	0044	MGG
155798	7	<2	4.20	245	<10	4200	0045	KG
155799	54	4	2.85	259	98	13200	0046	MGN
155800	21	<2	3.58	520	<10	5400	0047	KG
155801	65	3	3.10	196	97	7800	0048	MGN
155802	5	<2	3.99	287	<10	5400	0049	PEG
155803	100	4	1.05	693	58	3000	0050	CB
155804	119	17	6.26	156	68	9000	0051	DISL
155805	188	4	3.57	132	64	7800	0052	CB
155806	74	4	0.61	146	<10	5400	0053	PALD
155807	36	<2	4.17	390	33	6000	0054	MGN
155808	46	<2	4.38	442	42	7800	0055	GG

<2 7.95 <10 21 2 0.39 <4 5

OR SAMPLE NUMBER	D. O. E. SAMPLE ST LAT	LONG	NUMBER L TY REP	U (PPM)	U-NT (PPM)	U/TU	AG (PPM)	AL (%)	B (PPM)	BA (PPM)	BE (PPM)	CA (%)	CO (PPM)	CR (PPM)
155809	40-34.229	-113.601	-3-92-	1.16	1.40	0.83	<2	7.36	<10	1217	2	2.39	8	11
155810	40-34.071	-113.316	-3-92-	<0.25	0.23	0.54	<2	7.90	<10	5193	<1	0.85	<4	2
155811	40-34.067	-113.344	-3-92-	0.60	0.60	1.00	<2	7.87	<10	766	1	3.42	13	29
155812	40-34.077	-113.297	-3-92-	0.71	0.50	1.42	<2	8.23	<10	1287	1	3.89	15	8
155813	40-38.972	-114.195	-3-92-	7.90	10.20	0.77	<2	7.64	<10	145	5	0.75	<4	5
155814	40-38.964	-114.177	-3-92-	5.24	8.33	0.63	<2	7.79	<10	507	3	1.58	<4	6
155815	40-39.650	-114.168	-3-92-	1.39	3.00	0.46	<2	7.26	<10	1293	2	1.19	<4	6
155816	40-39.637	-114.059	-3-92-	9.67	10.80	0.90	<2	6.64	<10	83	3	0.54	<4	5
155817	40-32.309	-110.739	-3-92-	0.50	0.50	1.00	<2	7.66	<10	1571	1	0.69	<4	8
155818	40-32.309	-110.739	-3-92-	<0.25	0.60	0.21	<2	7.70	<10	285	1	0.90	<4	9
155819	40-32.309	-110.739	-3-92-	2.31	2.70	0.85	<2	6.87	<10	782	3	1.55	7	12
155820	40-32.311	-110.729	-3-92-	1.50	1.70	0.88	<2	7.30	<10	1335	1	1.17	<4	13
155821	40-32.311	-110.730	-3-92-	0.92	1.50	0.61	<2	6.65	<10	733	1	1.74	7	17
155822	40-32.311	-110.730	-3-92-	0.96	1.50	0.64	<2	7.15	<10	739	1	1.80	6	14
155823	40-32.311	-110.730	-3-92-	0.42	0.70	0.60	<2	7.21	<10	1441	1	1.02	<4	6
155824	40-32.311	-110.720	-3-92-	0.50	15.00	0.03	<2	7.43	<10	332	2	0.98	<4	9
155825	40-32.310	-110.721	-3-92-	0.54	2.00	0.27	<2	7.74	<10	187	1	0.87	<4	6
155826	40-32.310	-110.721	-3-92-	0.96	1.50	0.64	<2	7.49	<10	1701	1	1.03	<4	6
155827	40-32.316	-110.709	-3-92-	0.69	3.00	0.23	<2	7.28	<10	754	2	1.91	11	22
155828	40-32.317	-110.709	-3-92-	1.04	1.40	0.74	<2	7.57	<10	151	1	0.66	<4	4
155829	40-32.316	-110.709	-3-92-	0.57	1.10	0.52	<2	7.37	<10	1533	1	0.97	<4	10
155830	40-32.333	-110.694	-3-92-	2.49	2.80	0.89	<2	7.50	<10	875	1	2.48	12	23
155831	40-32.333	-110.694	-3-92-	0.59	0.80	0.74	<2	7.74	<10	78	1	0.83	<4	6
155833	40-32.338	-110.694	-3-92-	0.64	0.50	1.28	<2	7.28	<10	2972	<1	0.97	<4	8
155834	40-32.338	-110.694	-3-92-	0.49	0.50	0.98	<2	7.41	<10	2417	1	1.08	<4	6
155835	40-32.338	-110.694	-3-92-	2.33	2.70	0.86	<2	7.69	<10	789	2	2.18	16	23
155836	40-32.341	-110.717	-3-92-	0.45	1.10	0.41	<2	7.97	<10	2271	1	1.39	<4	6
155837	40-32.347	-110.717	-3-92-	0.30	0.70	0.43	<2	7.39	<10	1770	<1	1.17	<4	7
155838	40-32.351	-110.724	-3-92-	0.94	1.10	0.85	<2	7.32	<10	1923	1	1.12	<4	5
155839	40-32.361	-110.717	-3-92-	0.86	0.90	0.96	<2	7.06	<10	1038	1	0.82	<4	5
155840	40-32.362	-110.714	-3-92-	<0.25	1.05	0.12	<2	7.43	<10	1141	1	1.14	<4	6
155841	40-32.362	-110.714	-3-92-	4.15	6.30	0.65	<2	7.03	<10	541	1	0.74	7	14
155842	40-32.362	-110.714	-3-92-	1.34	1.80	0.74	<2	7.99	<10	605	1	0.41	<4	3
155843	40-32.362	-110.714	-3-92-	7.29	8.10	0.90	<2	7.29	<10	671	2	0.76	7	16
155844	40-******	-*******	-3-92-	4.40	4.90	0.90	<2	6.07	<10	592	3	1.60	7	17
155845	40-32.366	-110.709	-3-92-	1.42	1.30	1.09	<2	6.52	<10	903	1	0.69	<4	4
155846	40-32.370	-110.703	-3-92-	0.63	1.10	0.57	<2	6.74	<10	1777	1	0.90	<4	4
155847	40-32.372	-110.697	-3-92-	0.76	1.90	0.40	<2	7.04	3	189	2	0.64	<10	11
155848	40-32.378	-110.687	-3-92-	0.50	0.80	0.63	<2	7.94	2	1677	1	0.95	<10	9
155849	40-32.378	-110.687	-3-92-	1.43	1.50	0.95	<2	8.22	<10	567	2	0.71	<4	3
155850	40-32.368	-110.716	-3-92-	2.02	1.40	1.44	<2	7.97	<10	1936	1	0.95	<4	5
155851	40-32.368	-110.716	-3-92-	1.11	1.70	0.65	2	7.11	<10	127	2	0.51	<4	1
155852	40-32.384	-110.694	-3-92-	1.35	1.30	1.04	<2	7.48	<10	1030	2	0.87	<4	1
155853	40-32.401	-110.690	-3-92-	1.63	2.20	0.74	<2	7.60	<10	1012	3	0.83	<4	2
155854	40-32.405	-110.699	-3-92-	1.28	1.40	0.91	<2	7.15	<10	1320	2	0.96	<4	4
155855	40-32.411	-110.720	-3-92-	2.20	3.40	0.65	<2	8.06	<10	35	4	0.21	<4	2
155856	40-32.411	-110.720	-3-92-	0.50	2.90	0.17	<2	7.89	<10	1106	10	1.23	<4	7
155857	40-32.456	-110.784	-3-92-	0.33	33.10	0.01	<2	6.89	<10	70	6	0.62	<4	4
155859	40-32.456	-110.784	-3-92-	<0.25	11.70	0.01	<2	6.75	<10	52	5	0.58	<4	3
155860	40-32.448	-110.777	-3-92-	2.41	2.30	1.05	<2	1.70	14	160	1	0.30	5	13
155861	40-32.448	-110.777	-3-92-	1.07	6.40	0.17	<2	10.61	<10	704	6	0.20	38	61
155863	40-32.447	-110.761	-3-92-	0.54	3.30	0.16	<2	6.59	<10	1142	2	0.64	<4	3
155864	40-32.447	-110.761	-3-92-	0.87	4.20	0.21	<2	7.89	<10	929	11	2.71	13	32
155865	40-32.447	-110.761	-3-92-	2.19	3.60	0.61	<2	7.90	<10	20	4	0.19	<4	2
155868	40-32.436	-110.757	-3-92-	0.64	28.50	0.02	<2	7.95	<10	21	2	0.39	<4	5

OR SAMPLE NUMBER	CU (PPM)	FE (%)	LI (PPM)	MG (%)	MN (PPM)	MO (PPM)	NA (%)	NB (PPM)	NI (PPM)	P (PPM)	SC (PPM)	TH (PPM)	TI (PPM)	V (PPM)	Y (PPM)
155809	30	4.25	12	0.79	481	<4	2.70	11	10	1343	11	<2	4592	78	38
155810	7	0.63	4	0.08	106	<4	2.76	<4	<2	291	1	<2	334	5	1
155811	122	3.12	9	1.09	553	<4	3.03	4	28	640	8	5	2410	69	11
155812	27	4.95	10	1.60	885	<4	2.57	<4	18	929	12	<2	3347	97	22
155813	16	1.06	67	0.14	1062	<4	3.20	38	6	268	6	30	713	9	25
155814	7	1.62	18	0.25	623	<4	2.62	16	3	402	6	17	1327	22	15
155815	7	1.36	22	0.33	249	<4	2.09	7	4	518	2	10	965	15	11
155816	6	0.51	5	0.10	228	<4	2.44	11	7	209	2	53	624	7	4
155817	36	0.91	10	0.11	174	<4	2.06	5	9	169	5	<2	428	10	4
155818	14	1.13	9	0.11	744	<4	2.32	12	5	115	12	6	481	8	17
155819	28	4.34	22	0.73	818	<4	1.57	11	7	1521	15	22	5404	69	62
155820	24	1.63	9	0.22	270	<4	2.38	<4	9	233	4	14	986	12	16
155821	20	4.88	22	0.86	940	<4	1.84	7	11	2064	14	14	6177	69	39
155822	28	3.89	18	0.63	909	<4	2.21	12	10	1617	12	19	4390	50	43
155823	24	0.80	5	0.13	180	<4	2.05	<4	5	136	2	2	574	6	5
155824	30	0.79	5	0.10	2417	<4	2.91	4	5	90	2	<2	257	3	90
155825	33	0.80	5	0.06	1112	<4	2.69	8	7	96	5	2	227	3	41
155826	10	1.70	15	0.25	403	<4	2.10	4	3	136	5	20	1122	11	19
155827	50	6.05	23	1.11	1703	<4	1.92	19	15	2333	22	30	7399	72	61
155828	12	0.77	4	0.07	859	<4	2.23	13	3	54	8	<2	230	2	22
155829	53	0.95	6	0.13	195	<4	1.98	<4	6	206	2	7	537	8	13
155830	65	4.19	30	1.29	899	<4	1.70	6	15	1099	10	11	3935	101	18
155831	18	0.65	6	<0.05	592	<4	2.84	7	3	74	4	<2	130	3	18
155833	10	0.96	4	0.09	107	<4	2.01	<4	6	222	1	7	429	6	4
155834	14	0.88	5	0.10	135	<4	2.27	<4	6	108	1	4	484	6	3
155835	20	6.45	18	1.31	1201	<4	1.00	9	17	2650	24	17	8118	111	74
155836	9	2.64	15	0.47	402	<4	2.26	4	6	968	6	8	2468	27	14
155837	9	1.84	14	0.30	290	4	2.28	<4	6	687	4	5	1563	16	9
155838	11	1.26	10	0.19	251	<4	2.21	<4	3	331	3	14	877	11	7
155839	10	0.93	10	0.11	212	<4	2.12	4	2	127	3	8	722	5	5
155840	12	1.20	9	0.17	279	<4	2.70	4	5	126	4	2	746	7	2
155841	64	4.98	21	1.04	1450	<4	1.57	24	10	413	22	37	5287	45	23
155842	9	0.64	5	0.07	995	<4	1.66	19	4	158	14	<2	420	6	4
155843	29	4.41	27	1.07	1306	<4	1.40	16	10	1346	19	27	4994	48	29
155844	31	3.75	42	0.48	765	<4	1.55	7	9	2298	11	18	3600	59	47
155845	18	0.56	5	0.08	1130	<4	2.07	8	4	297	4	<2	193	2	10
155846	76	1.19	9	0.15	223	<4	2.17	8	3	178	3	4	695	6	5
155847	12	1.11	21	0.17	[illegible]	<4	2.52	6	15	180	3	<2	[illegible]	7	6
155848	6	0.99	23	[illegible]	[illegible]	<4	[illegible]	5	7	133	4	<2	[illegible]	7	5
155849	8	0.58	8	0.08	539	<4	2.92	10	4	117	2	5	270	2	8
155850	13	1.49	20	0.20	545	<4	2.69	12	4	208	3	5	1021	6	8
155851	52	0.40	4	<0.05	735	<4	3.43	11	2	200	1	<2	96	<2	8
155852	6	1.03	27	0.15	422	<4	2.73	9	3	253	3	3	660	4	15
155853	7	1.99	45	0.26	1040	<4	2.53	15	<2	270	4	<2	1379	12	12
155854	5	0.98	23	0.14	458	<4	2.56	8	3	190	2	2	602	5	5
155855	31	0.57	16	<0.05	5093	<4	4.13	143	2	266	<1	<2	110	<2	3
155956	26	1.73	117	0.35	639	<4	2.68	16	6	911	3	5	1628	20	17
155857	12	0.73	33	0.14	533	<4	2.98	40	3	140	3	26	1047	6	24
155859	7	0.60	23	0.10	442	<4	2.90	38	4	123	2	26	829	4	21
155860	20	1.68	12	0.15	120	<4	<0.05	4	8	570	3	5	3245	34	21
155861	389	2.55	53	0.75	310	<4	0.34	<4	34	579	19	28	5062	112	37
155963	46	0.94	7	0.16	379	4	2.18	13	2	229	3	16	1151	6	12
155864	8	4.17	236	1.66	777	<4	2.12	<4	22	1384	9	5	4082	106	14
155865	8	0.36	1	<0.05	2929	<4	4.46	150	4	358	<1	9	38	<2	2
155868	4	3.30	32	0.13	34419	<4	2.74	24	2	259	9	50	280	<2	269

METAMORPHIC CCRE CCMPLEXES

OR SAMPLE NUMBER	ZN (PPM)	ZR (PPM)	K (%)	SR (PPM)	CE (PPM)	TGAM (CPS)	SITE	S-GC
155809	75	2	2.47	390	62	6000	0056	MGM
155810	14	<2	3.62	627	<10	4200	0057	KG
155811	57	3	1.29	409	25	2400	0058	AMPH
155812	97	2	1.62	313	18	3000	0059	GG
155813	101	15	2.08	63	46	8400	0060	JGR
155814	73	6	2.39	210	35	9000	0061	JGR
155815	77	7	2.23	349	79	6600	0062	TMG
155816	35	23	2.79	55	20	13200	0063	TG
155817	39	<2	3.35	347	<10	6000	0064	PEG
155818	36	<2	2.37	158	13	5400	0065	PEG
155819	84	3	2.33	149	158	7800	0066	GG
155820	61	<2	2.62	328	73	6600	0067	TGD
155821	135	2	1.67	229	121	7200	0068	GG
155822	121	2	1.45	272	160	7200	0069	GG
155823	36	<2	2.58	324	28	5400	0070	TGD
155824	34	2	1.90	192	<10	5400	0071	PEG
155825	34	2	2.01	152	13	6000	0072	PEG
155826	66	2	2.34	365	82	6600	0073	TGD
155827	207	3	1.98	199	128	7800	0074	GG
155828	46	2	2.65	121	<10	6000	0075	PEG
155829	50	2	3.03	297	47	6000	0076	TGR
155830	114	3	1.98	445	57	5400	0077	TGD
155831	30	2	2.60	70	<10	6000	0078	PEG
155833	25	<2	2.71	489	34	6000	0079	TMG
155834	40	<2	2.43	467	30	6000	0080	TMG
155835	191	2	1.58	252	154	5400	0081	YG
155836	99	<2	2.38	516	61	5400	0082	TMG
155837	64	<2	2.51	463	43	5400	0083	TMG
155838	66	2	2.27	518	96	6000	0084	TMG
155839	47	<2	2.15	257	28	5400	0085	TMG
155840	82	<2	1.77	294	21	6600	0086	TMG
155841	307	3	2.32	143	213	10200	0087	MS
155842	47	2	3.48	166	<10	8400	0088	PEG
155843	180	3	3.01	107	209	9600	0089	YG
155844	97	3	2.11	127	134	9000	0090	YG
155845	32	<2	2.24	216	<10	4800	0091	TMG
155846	46	<2	1.98	350	31	5400	0092	TMG
155847	96	2	2.23	340	37	5400	0093	TMG
155848	50	2	2.33	337	33	4800	0094	TMG
155849	43	6	1.89	161	22	5400	0095	PEG
155850	120	<2	2.32	376	35	4800	0096	TMG
155851	598	5	1.74	57	<10	5400	0097	PEG
155852	67	<2	2.03	274	29	4800	0098	TMG
155853	112	2	2.14	230	49	5400	0099	TMG
155854	47	<2	1.98	333	21	4800	0100	TMG
155855	38	11	1.61	34	<10	4800	0101	PEG
155856	85	<2	2.09	414	62	5400	0102	TMG
155857	39	6	1.90	31	51	10800	0103	TG
155859	28	6	1.83	29	57	10800	0105	TG
155860	24	2	0.91	54	62	3600	0106	YQ
155861	152	4	4.46	269	134	9000	0107	YSCH
155863	28	22	2.52	175	57	8400	0108	TD
155864	137	2	1.47	512	40	6000	0109	TGD
155865	63	12	1.27	12	12	5400	0110	AP
155868	258	68	0.66	10	53	8400	0113	GS

OR SAMPLE NUMBER	D. O. E. SAMPLE ST LAT	LONG	NUMBER L TY REP	U (PPM)	U-NT (PPM)	U/TJ	AG (PPM)	AL (%)	B (PPM)	BA (PPM)	BE (PPM)	CA (%)	CO (PPM)	CR (PPM)
155869	40-32.436	-110.757	-3-92-	1.74	5.00	0.35	<2	8.16	<10	969	4	2.84	13	32
155870	40-32.433	-110.752	-3-92-	10.90			<2	7.04	<10	19	2	0.21	<4	11
155871	40-32.573	-111.028	-3-92-	0.56	0.80	0.70	<2	9.00	<10	581	1	5.33	25	31
155872	40-32.524	-111.074	-3-92-	<0.25	0.90	0.14	<2	7.41	<10	1345	1	0.83	<4	12
155873	40-32.548	-111.032	-3-92-	2.41	4.20	0.57	<2	7.64	<10	768	2	1.93	6	18
155874	40-32.549	-111.020	-3-92-	2.25	3.60	0.63	<2	7.73	<10	928	2	1.90	6	18
155875	40-32.532	-111.076	-3-92-	1.29	1.90	0.68	<2	8.47	<10	530	5	2.66	11	22
155876	40-32.532	-111.076	-3-92-	2.34	2.60	0.90	<2	8.12	<10	891	3	2.96	11	26
155877	40-32.532	-111.076	-3-92-	<0.25	0.80	0.16	<2	7.45	<10	898	1	1.27	<4	10
155878	40-32.540	-111.047	-3-92-	3.04	3.50	0.87	<2	7.95	<10	1132	2	2.51	10	23
155879	40-32.483	-111.081	-3-92-	1.61	2.30	0.70	<2	8.93	<10	1734	2	3.91	17	37
155880	40-32.484	-111.081	-3-92-	1.07	1.80	0.59	<2	7.60	<10	1224	2	1.85	6	22
155881	40-32.489	-111.077	-3-92-	0.71	1.50	0.47	<2	8.03	<10	1333	2	2.43	9	31
155882	40-32.489	-111.077	-3-92-	1.14	1.70	0.67	<2	8.31	<10	1578	2	2.50	9	26
155883	40-32.457	-110.966	-3-92-	0.80	2.90	0.28	<2	6.66	<10	193	2	0.54	<4	13
155884	40-32.474	-110.982	-3-92-	2.54	6.00	0.42	<2	6.38	<10	1195	2	1.01	15	33
155885	40-32.476	-110.981	-3-92-	0.86	2.70	0.32	<2	6.98	<10	988	2	0.93	<4	11
155886	40-32.476	-110.979	-3-92-	3.50	6.70	0.52	<2	6.17	<10	89	3	0.37	<4	12
155887	40-32.478	-110.978	-3-92-	0.76	2.10	0.35	<2	6.78	<10	904	2	1.00	<4	14
155888	40-32.465	-111.030	-3-92-	0.61	1.60	0.38	<2	6.99	<10	1172	2	1.02	<4	8
155889	40-32.473	-111.089	-3-92-	0.91	4.00	0.23	<2	6.38	<10	572	3	1.43	4	22
155891	40-32.586	-111.030	-3-92-	2.21	3.60	0.61	<2	7.97	<10	2313	2	0.52	<4	9
155892	40-32.583	-111.029	-3-92-	2.42	4.80	0.50	<2	7.97	<10	2557	2	0.47	<4	14
155893	40-32.582	-111.029	-3-92-	2.33	3.60	0.65	<2	7.59	<10	2128	2	0.88	<4	14
155894	40-32.581	-111.029	-3-92-	0.94	2.30	0.41	<2	6.07	<10	668	3	0.16	15	87
155895	40-32.576	-111.028	-3-92-	1.99	4.00	0.50	<2	6.98	<10	978	2	0.45	6	69
155896	40-32.573	-111.028	-3-92-	1.78	3.50	0.51	<2	7.85	<10	813	2	2.33	8	17
155897	40-32.573	-111.028	-3-92-	1.53	2.36	0.65	<2	8.14	<10	842	1	3.01	12	19
155898	40-32.592	-111.033	-3-92-	1.16	1.60	0.73	<2	6.55	<10	966	1	1.39	8	16
155899	40-32.580	-111.091	-3-92-	3.01	2.60	1.16	<2	6.41	<10	799	6	1.00	6	24
155900	40-32.580	-111.091	-3-92-	0.76	1.89	0.40	<2	4.46	<10	590	2	0.44	5	36
155901	40-32.581	-111.093	-3-92-	2.21	3.30	0.67	<2	6.86	<10	879	3	1.16	5	15
155902	40-32.623	-111.045	-3-92-	1.98	3.50	0.57	<2	10.03	<10	729	2	0.54	15	63
155903	40-32.957	-110.655	-3-92-	1.21	1.50	0.81	<2	7.64	<10	1304	1	1.70	10	12
155904	40-32.478	-110.978	-3-92-	0.80	2.00	0.40	<2	6.90	<10	864	2	0.93	<4	9
155905	40-32.478	-111.093	-3-92-	0.44	2.50	0.18	<2	6.82	<10	1066	2	1.25	4	14
155906	40-32.526	-111.039	-3-92-	1.33	2.70	0.49	<2	3.47	<10	694	1	0.48	4	54
155907	40-32.560	-111.107	-3-92-	0.54	1.10	0.49	<2	6.95	<10	1433	1	0.72	<4	9
155908	40-32.502	-111.034	-3-92-	2.37	2.90	0.82	<2	7.26	<10	1423	2	1.13	<4	16
155909	40-32.494	-111.041	-3-92-	2.23	3.40	0.66	<2	6.88	<10	1192	2	0.62	<4	17
155910	40-32.563	-111.078	-3-92-	<0.25	0.50	0.25	<2	6.82	<10	1617	1	0.83	<4	9
155911	40-32.557	-111.113	-3-92-	<0.25	0.60	0.21	<2	7.91	<10	1406	2	1.29	<4	13
155912	40-32.557	-111.113	-3-92-	0.46	1.10	0.42	<2	6.96	<10	1823	1	0.95	<4	9
155913	40-32.556	-111.060	-3-92-	0.82	1.20	0.68	<2	7.48	<10	829	1	4.50	25	127
155914	40-32.312	-110.740	-3-92-	<0.25	0.60	0.21	<2	7.37	<10	512	2	1.84	<4	7
155915	40-32.311	-110.725	-3-92-	2.36	4.50	0.52	<2	6.93	<10	1049	3	1.42	6	18
155916	40-32.322	-110.707	-3-92-	1.95	2.40	0.81	<2	6.73	<10	856	2	1.75	8	22
155917	40-32.332	-110.695	-3-92-	0.68	1.20	0.57	<2	6.82	<10	746	3	1.93	6	20
155918	40-32.340	-110.695	-3-92-	<0.25	0.30	0.42	<2	8.14	<10	2150	1	1.59	<4	15
155919	40-32.370	-110.702	-3-92-	<0.25	0.60	0.21	<2	6.91	<10	1372	1	0.77	<4	14
155920	40-32.401	-110.689	-3-92-	0.36	1.20	0.30	<2	7.05	<10	1150	2	0.76	<4	11
155921	40-32.447	-110.757	-3-92-	2.62	2.90	0.90	<2	7.72	<10	943	7	2.69	10	27
155922	40-32.489	-111.077	-3-92-	2.94	2.80	1.05	<2	8.45	<10	1214	3	4.64	21	55
155923	40-32.325	-110.775	-3-92-	0.50	0.90	0.56	<2	8.82	<10	1142	2	2.12	4	6
155924	40-32.300	-110.500	-3-92-	10.28	1780.00	0.01	<2	7.23	<10	535	3	4.93	14	45

OR SAMPLE NUMBER	CU (PPM)	FE (%)	LI (PPM)	MG (%)	MN (PPM)	MO (PPM)	NA (%)	NB (PPM)	NI (PPM)	P (PPM)	SC (PPM)	TH (PPM)	TI (PPM)	V (PPM)	Y (PPM)
155869	5	4.28	115	1.73	1084	<4	2.18	4	19	1608	10	8	4242	109	15
155870	26	3.53	26	0.11	41525	<4	1.20	55	<2	178	10	20	318	<2	256
155871	63	6.21	35	2.74	1043	<4	2.29	<4	48	1312	20	4	6280	204	23
155872	5	0.56	6	0.05	129	<4	2.62	6	26	91	4	<2	381	7	1
155873	64	2.17	45	0.75	515	<4	2.51	4	29	595	5	8	2435	59	10
155874	37	2.03	34	0.67	503	<4	2.54	6	30	543	4	7	2456	55	12
155875	26	3.57	34	1.20	1073	<4	2.97	4	32	778	8	8	3513	96	16
155876	30	3.49	21	1.16	741	<4	2.43	4	31	707	8	5	3339	94	15
155877	14	0.52	5	0.09	186	<4	3.08	<4	27	74	1	<2	288	6	2
155878	43	3.27	50	1.11	723	<4	2.31	6	35	830	7	7	3442	88	15
155879	74	5.08	18	1.91	779	<4	2.57	12	61	2548	12	9	7261	142	29
155880	33	2.49	18	0.76	541	<4	2.47	14	34	1121	6	6	3554	58	25
155881	29	3.48	18	1.11	782	<4	2.62	17	42	1700	8	<2	4753	85	33
155882	33	3.39	14	1.15	743	<4	2.41	15	38	1616	9	3	4597	86	30
155883	4	0.47	12	0.06	127	<4	2.71	6	25	148	2	12	361	4	3
155884	115	7.22	72	1.69	1385	<4	1.45	12	45	2003	11	14	6379	124	40
155885	9	1.00	19	0.25	300	<4	2.21	6	25	285	2	30	946	14	10
155886	8	0.25	5	<0.05	69	<4	2.08	9	22	111	2	11	247	2	9
155887	8	1.03	26	0.27	334	<4	2.19	7	25	307	3	8	998	15	7
155888	15	1.13	21	0.20	263	<4	2.29	<4	23	269	2	13	947	15	5
155889	14	1.58	19	0.43	547	<4	1.93	13	26	920	10	11	2648	32	12
155891	10	1.31	16	0.33	149	<4	3.00	10	6	413	2	14	1226	30	9
155892	128	1.70	15	0.43	556	6	2.64	7	7	694	3	12	713	28	11
155893	7	1.67	14	0.43	570	<4	2.94	<4	9	619	3	18	752	32	6
155894	8	3.00	31	0.71	422	<4	1.19	<4	31	426	10	11	883	47	7
155895	49	2.55	21	0.56	324	<4	0.33	9	24	316	11	9	3498	55	31
155896	37	2.67	23	0.94	559	<4	2.33	<4	12	778	7	6	2822	77	12
155897	12	3.74	42	1.44	715	<4	2.24	5	17	880	8	4	3982	100	20
155898	26	3.64	28	0.69	789	<4	1.46	9	12	1501	13	16	5168	62	40
155899	22	2.15	28	0.39	712	<4	1.59	11	14	616	9	22	2548	40	53
155900	7	1.83	25	0.29	272	<4	0.69	4	13	678	6	7	1614	28	20
155901	32	2.60	31	0.35	675	<4	1.92	11	9	874	10	17	2896	53	47
155902	30	4.31	61	0.93	833	<4	1.29	4	33	528	18	7	3188	81	15
155903	21	4.14	28	0.98	642	<4	1.52	7	10	1222	10	5	3782	114	15
155904	7	0.88	27	0.23	245	<4	2.26	7	11	236	3	14	793	12	5
155905	20	2.01	16	0.39	471	<4	1.65	11	8	850	10	16	2435	32	11
155906	4	1.92	37	0.24	289	<4	0.87	5	12	361	4	9	2066	32	6
155907	5	0.87	5	0.11	391	<4	2.45	11	4	325	2	3	564	8	6
155908	10	1.46	8	0.31	358	<4	2.29	7	8	438	3	15	1438	22	10
155909	7	1.29	7	0.26	268	<4	2.36	6	5	330	2	20	1112	18	10
155910	16	0.66	10	0.12	333	<4	2.42	6	4	198	2	4	343	5	3
155911	7	0.44	7	0.06	120	<4	3.34	<4	<2	142	1	<2	347	5	3
155912	36	1.08	11	0.16	388	<4	2.50	6	<2	282	2	4	503	5	9
155913	45	6.84	29	2.97	987	<4	1.95	<4	66	2419	17	6	8805	162	31
155914	13	1.19	11	0.19	219	<4	2.98	<4	2	109	3	9	930	14	7
155915	24	3.33	18	0.61	868	<4	1.90	9	7	1023	13	23	4246	54	56
155916	13	3.93	23	0.72	937	<4	1.85	10	9	1228	13	19	5103	69	50
155917	10	2.55	20	0.78	704	<4	2.18	15	8	1142	6	6	2195	48	17
155918	2	0.70	5	0.10	118	<4	3.25	<4	4	133	1	3	468	5	3
155919	6	0.66	6	0.06	217	<4	2.47	7	3	146	4	8	369	4	4
155920	2	1.28	35	0.15	530	<4	2.69	10	<2	160	3	8	776	8	6
155921	<2	3.38	113	1.36	531	<4	2.24	<4	18	919	7	10	3443	90	15
155922	91	6.23	20	2.25	927	<4	2.58	13	62	2950	15	9	7418	168	35
155923	7	2.31	27	0.45	354	<4	3.32	<4	4	1079	4	6	2209	35	10
155924	523	4.19	49	2.67	1183	41	0.13	17	23	536	13	34	3520	53	60

OR SAMPLE NUMBER	ZN (PPM)	ZR (PPM)	K (%)	SR (PPM)	CE (PPM)	TGAM (CPS)	SITE	S-GC
155869	213	3	1.55	557	44	5400	0114	TGD
155870	121	46	1.24	6	43	9600	0115	GS
155871	114	12	1.03	750	43		0116	TED
155872	22	<2	2.70	317	<10		0117	TMG
155873	81	3	2.28	463	36		0118	TED
155874	71	3	2.20	507	42		0119	TGD
155875	133	<2	1.25	506	44		0120	TGD
155876	88	2	1.76	654	36		0121	TGD
155877	30	<2	2.01	398	<10		0122	TMG
155878	89	3	2.14	554	43		0123	TGD
155879	113	10	1.76	837	140		0124	INC
155880	70	5	2.63	459	108		0125	TG
155881	90	6	2.04	533	115		0126	TG
155882	82	6	2.20	597	116		0127	TG
155883	16	5	2.77	76	26		0128	TD
155884	202	2	3.09	147	103		0129	INC
155885	36	4	2.77	227	25		0130	TG
155886	12	9	2.63	29	<10		0131	APL
155887	39	2	2.42	209	39		0132	TG
155888	43	2	2.72	288	57		0133	TG
155889	38	<2	1.98	141	79		0134	YG
155891	23	6	1.43	450	24		0136	YD
155892	43	6	1.73	432	35		0137	YD
155893	42	5	1.53	353	69		0138	YD
155894	71	2	1.64	58	65		0139	YS
155895	62	3	2.58	73	73		0140	YS
155896	60	3	1.24	415	42		0141	TGD
155897	73	3	1.38	588	48		0142	TGD
155898	89	2	2.21	147	106		0143	YD
155899	64	3	2.35	163	119		0144	YD
155900	40	2	1.47	72	54		0145	YS
155901	71	2	2.54	196	100		0146	YD
155902	96	96	2.35	98	70		0147	YS
155903	82	59	2.70	322	40		0148	KV
155904	23	2	2.61	197	42		0149	TG
155905	42	<2	2.55	168	72		0150	YD
155906	39	<2	1.51	107	60		0151	MS
155907	36	<2	2.38	243	51		0152	TMG
155908	36	3	2.58	341	92		0153	TG
155909	28	3	2.87	321	76		0154	TG
155910	36	<2	1.80	355	23		0155	TMG
155911	11	<2	1.88	638	22		0156	TMG
155912	41	<2	2.60	295	73		0157	TMG
155913	107	27	0.92	553	78		0158	TD
155914	41	<2	1.06	328	47		0159	YD
155915	69	3	2.57	165	223		0160	YD
155916	101	2	2.09	165	70		0161	YD
155917	109	<2	1.37	369	39		0162	TGD
155918	19	<2	1.95	536	26		0163	TG
155919	34	<2	2.36	265	29		0164	TMG
155920	49	<2	2.38	230	32		0165	TMG
155921	51	4	1.74	544	46		0166	TGD
155922	116	13	1.35	743	120		0167	INC
155923	72	<2	1.43	763	76		0168	TGD
155924	122	12	2.54	169	123		0169	BRD

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          METAMORPHIC CORE COMPLEXES                                                                   PAGE  4 SECTION  1 OF  3

 OR SAMPLE  D. O. E. SAMPLE  NUMBER         U    U-NT    U/TJ     AG      AL       B      BA      BE      CA      CO      CR
  NUMBER ST  LAT      LONG   L TY REP    (PPM)   (PPM)          (PPM)    (%)    (PPM)   (PPM)   (PPM)    (%)    (PPM)   (PPM)
 155925  40-32.301 -110.501 -3-92-        2.53 2060.00   0.00     <2     6.83    <10     581       2    5.46      13      37
 155926  40-32.300 -110.500 -3-92-       97.52  106.80   0.91     <2     8.50    <10     808       4    2.91      18      16
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          METAMORPHIC CORE COMPLEXES                                                                   PAGE  4 SECTION  2 OF  3

OR SAMPLE     CU       FE      LI      MG      MN      MO      NA      NB      NI       P      SC      TH      TI       V       Y
 NUMBER     (PPM)     (%)    (PPM)    (%)    (PPM)   (PPM)    (%)    (PPM)   (PPM)   (PPM)   (PPM)   (PPM)   (PPM)   (PPM)   (PPM)
 155925      372     3.66      43    2.38    1166      50    0.12      11      22     508      12      36    2976      43      57
 155926      521     4.07      41    1.33    1095       5    0.42      12      11    1177      15      30    2644      57      98
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          METAMORPHIC CORE COMPLEXES                                                                   PAGE  4 SECTION  3 OF  3

 OR SAMPLE     ZN      ZR       K      SR      CE    TGAM    SITE    S-GC
  NUMBER     (PPM)   (PPM)    (%)    (PPM)   (PPM)   (CPS)
  155925      125      10    2.80     156     119            0170    BRO
  155926      194      11    2.23     104     211            0171    BRO
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PETROLOGIC SUMMARY OF THE EOCENE WILDERNESS GRANITE AND RELATED ROCKS, SANTA CATALINA MOUNTAINS, ARIZONA

by

James F. DuBois

Mineralogy

The mineralogy of the Wilderness Granite and related rocks of the Santa Catalina Mountains of Arizona is quite simple. The major minerals are plagioclase, alkali feldspar, and quartz. Accessory minerals include magnetite, garnet, apatite, and zircon. Plagioclase is the most abundant mineral throughout the plutonic complex, ranging in modal abundance from 20 to 60 percent; an average of 35 percent is typical for the rocks. Generally, plagioclase is less abundant in the pegmatitic phases and more abundant lower in the sequence. The plagioclase occurs both as euhedral phenocrysts and finer interstitial grains. Anorthite content of the plagioclase ranges from 10 to 20 percent. Albite and Carslbad twinning are present, as are delicate oscillatory and normal zoning.

Alkali feldspar is generally less abundant than plagioclase and ranges from 5 to 45 percent in modal abundance. In all of the rocks examined alkali feldspar occurs as anhedral grains ranging from 1mm to several centimeters in diameter. The larger grains are common in the pegmatitic rocks. Some of the larger alkali feldspars are poikilitic with oikocrysts of euhedral plagioclase or muscovite. Finer-grained alkali feldspar is commonly intergrown with quartz in a micrographic texture.

Quartz is ubiquitous within the samples studied, comprising between 20 and 50 percent of any given rock. It is more abundant in rocks from the upper portions of the complex, but averages a little over 30 percent overall. No phenocrysts of quartz are present; instead, the mineral is fine-grained and interstitial except where recrystallized to form lensoid blasts. Undulatory extinction is characteristic.

Muscovite occurs in almost all of the samples and ranges from a trace to 20 percent modal abundance. Two types of muscovite have been identified which may be distinguished on the basis of color. Light-green, celadonitic muscovite appears as coarse, blocky plates up to 5mm in length. It is phenocrystic and one of the earliest formed minerals. Green muscovite does not occur below the level of sampling represented by sample 155828. White muscovite is of a finer grain size than green muscovite. White muscovite appears as very fine-grained aggregates surrounding green muscovite. The white muscovite is invariably oriented parallel to foliation in the rocks and is interpretted to have been devoloped during deformation. Concentration of opaque minerals along the cleavages in white muscovite may represent metals exsolved out of the muscovite during its conversion from green to white.

Biotite appears in all of the rocks except some of the pegmatitic phases. It ranges from a trace to nearly 20 percent in abundance, with the lower portions of the complex being more biotite rich. The biotite occurs as fine aggregates of platelets, but also forms coarser grains up to 3mm long. As with muscovite, finer-grained biotite parallels foliation in the rocks while coarser grains appear randomly distributed in original igneous textural relationships. No petrographic evidence could be found for any systematic chemical variation in biotite composition.

Garnet is common among trace minerals found in the rocks and is another expression of their peraluminous character (see Chapter 5 for a more complete discussion of the geochemistry of these rocks). The garnets are less than 0.3mm in diameter except for certain pegmatitic samples. Garnet crystals are euhedral and pink. Garnet appears to have formed early since it occurs as inclusions in coarse, green muscovite and other minerals. Garnet is never found in rocks that do not contain coarse green muscovite; therefore it only occurs in upper parts of the plutonic complex. Garnet is not a product of mylonitic deformation because it occurs in rocks that are undeformed. Where garnet is found in deformed rocks, the foliation wraps around garnet grains.

Two samples contain approximately 30 percent garnet(samples 155868 and 155870) and deserve special mention. These rocks appear to be equigranular garnet-muscovite aplite; these rocks are described as garnet schlieren in Chapters 4 and 5. The muscovite is fine-grained, greenish and stubby. Plagioclase is fine-grained and subhedral. Quartz is fine- to very fine-grained, anhedral and interstitial. These four minerals are present in sub-equal amounts whereas alkali feldspar and opaques are absent. A trace of acicular apatite and sphene occur as minute inclusions in the garnet. The extreme abundance of garnet as well as the aplitic texture of these samples indicates that they represent highly differentiated igneous rocks. As discussed in Chapter 5, these rocks have high uranium contents, as much as 28.5 ppm.

Apatite, zircon, and rarely sphene are present in trace amounts. These minerals are euhedral and fine-grained. Apatite is rod-like and is usually included in recrystallized quartz. Zircon is present in only one sample studied; it is clear and lacks overgrowths. The rocks are rather unique in their general lack of accessory minerals.

Grains of corundum were observed in a few thin sections of garnet-muscovite pegmatites. The corundum is 0.5mm in diameter or smaller. It has high relief and is clear with low first-order interference colors. The grains show rhombohedral cross-sections.

Textures

In undeformed rocks of the complex, original igneous textures are preserved and the paragenetic relationships are relatively clear. Plagioclase, green muscovite, and coarse-grained biotite can be regarded as early-formed minerals because they are coarse, euhedral, and poikilitically included by other mineral phases. Plagioclase show delicate oscillatory and normal zoning indicating a possible history as a solid phase circulating within a fluid melt. Two alkali feldpars and quartz comprise the interstitial crystallization products. These are fine-grained with serrate grain boundaries. Myrmekitic intergrowths are common in the interstitial material, imparting a micrographic texture that is characteristic of shallow intrusion. High water pressure is implied by petrography and field relationships of the rocks. The high water pressure may be manifest primarily in the appearence of extensive pegmatitic phases (see Keith and others, 1980; and Keith and Reynolds, Chapter 5 of this report). Pegmatitic rocks are primarily found in the upper parts of the complex. Alkali feldspars and muscovite are quite coarse-grained and modal percentages cannot be accurately determined from thin sections. Granophyric texture is predominant with phenocrystic phases only identifiable where they are engulfed by large alkali feldspar grains.

A spectrum of intensity of deformation is represented in the samples examined during this study. A detailed discussion of mineralogic and textural changes between undeformed and highly mylonitic rocks is included in Chapter 5 which also discusses the chemical changes (or lack thereof) undergone by the rocks during mylonitization. In general, the more deformed rocks are found in the lower parts of the plutonic complex (Keith and others, 1980). The deformation may be characterized as somewhat brittle and low temperature. No blastic developement is present and the large feldspar grains are more accurately termed porphyroclasts. Foliation is represented microscopically by planes of intense deformation. Less competent minerals such as biotite and muscovite can be seen to have behaved fairly plastically, while the feldspars were cracked and physically eroded during the mylonitic deformation (see Chapters 4 and 5 for discussions of similar results obtained from other core complexes).

Conclusions

Petrologically, the system is quite simple. Plagioclase is more abundant than alkali feldspar (predominantly orthoclase). Muscovite, garnet and corundum attest to the peraluminous nature of the inturion. The lack of accessory minerals in the plutonic complex suggests that the original melt was depleted in many of the rarer large-ion elements that facilitate the formation of minerals such as zircon. A shallow depth of intrusion is implied by micrographics textures and field relationships (Keith and others, 1980; Banks, 1980). High water pressure is clearly indicated for the crystallizing magma. Igneous textures formed during this crystallization are overprinted by deformational fabric. The deformation appears to have been a brittle processes involving the physical breakdown of feldspars. Foliation is primarily defined by mica minerals 'smeared'out along shear planes in the rock. No blastic development is present.