Lawrence Radiation Laboratory
UNIVERSITY OF CALIFORNIA
LIVERMORE

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**MINERAL COMPOSITION, CO₂ CONTENT, AND GRAIN DENSITY
OF DRILL HOLE SAMPLES
FROM YUCCA FLAT, NEVADA TEST SITE**

L. D. Ramspott

R. L. Braun

W. F. Wadleigh

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MINERAL COMPOSITION, CO₂ CONTENT, AND GRAIN DENSITY OF DRILL HOLE SAMPLES FROM YUCCA FLAT, NEVADA TEST SITE

Abstract

Mineral composition, CO₂ content, and grain density have been determined for 148 samples from 108 drill holes in Yucca Flat, Nevada Test Site. The amounts of calcite, dolomite, and quartz were quantitatively determined by x-ray diffraction using an internal standard. All other minerals were identified, and qualitative estimates of the x-ray intensities of zeolite, feldspar, and illite are given.

The mean weight-percent values for 119 alluvium samples are: calcite 5.9, dolomite 4.5, and CO₂ 4.77. The median values for the same samples are: cal-

cite 2.5, dolomite 1.5, and CO₂ 3.60. The modal classes are: calcite 1-2 (wt%), dolomite 0-1, and CO₂ 0-1.

Although two-thirds of the holes had only cuttings samples for the alluvium interval, analysis of size fractions of suitable samples indicates that cuttings samples provide a usable indicator of the carbonate content of the original rock.

In general, grain density does not correlate quantitatively with any one mineral, but in a suite of samples from one drill hole the correlation coefficient between dolomite and grain density was 0.933.

Introduction

Noncondensable gas (CO₂) is generated by nuclear explosions in rocks containing carbonate minerals. The common carbonate minerals, calcite and dolomite, have 44 and 48 wt% CO₂, respectively. Large concentrations of either mineral could lead to high cavity-gas pressure at times after detonation when water-vapor pressure in the cavity has declined to insignificant levels.

This report presents data for 148 samples from 108 drill holes in Yucca Flat, Nevada Test Site. Most samples are of alluvium, although there are 27 tuff sam-

ples and 2 dolomite samples. Most samples are from Areas 2, 9, and 10.

The main objective of the study was to obtain information on the distribution of dolomite and calcite. Distinguishing dolomite from calcite is important because dolomite is reported to start decomposition at a temperature about 400°C lower than calcite for a given pressure.¹ Thus, for a given energy deposition by an explosion, dolomite would release more CO₂ than calcite.

A secondary objective was to obtain general compositional data. Thus,

Table 1. Summary of CO₂ analyses of Yucca Flat alluvium available before present study.^a

Location	Depth interval (ft)	CO ₂ (wt%)	Source
U2ab	590-610	0.9	USGS files
U2ab	610-630	0.1	USGS files
U2ab	630-650	1.1	USGS files
U3ah	1198-1203	0.73	Ref. 2
U3ai	1200	5.9	Ref. 2
U3cy	485	2.2	USGS files
U3cy	840	2.9	USGS files
U3cy	860	10.4	USGS files
U5b	590-610	4.8	USGS files
U5b	610-630	5.2	USGS files
U5b	630-650	6.3	USGS files
U6a	400	3.6	Ref. 3
YF-1	Surface	4.5	USGS files
YF-2	Surface	7.7	USGS files
YF-3	Surface	5.87	USGS files
YF-4	Surface	4.97	USGS files
YF-5	Surface	11.99	USGS files
YF-6	Surface	4.17	USGS files
YF-7	Surface	7.58	USGS files
YF-8	Surface	17.0	USGS files
YF-9	Surface	18.39	USGS files
YF-10	Surface	13.5	USGS files
YF-11	Surface	11.4	USGS files
YF-12	Surface	15.8	USGS files
YF-13	Surface	6.4	USGS files
U10aj-b	~625	7.27	LRL files
U2bm	690-760 (composite)	3.65	LRL files
U10aj-f	510-15	0.85	LRL files
U10aj-f	550-55	0.88	LRL files
U10aj-f	600-05	1.00	LRL files
U10aj-f	610-15	1.01	LRL files
U10aj-f	620-25	4.76	LRL files
U10aj-f	640-45	2.33	LRL files

^aSamples from U2ab and U5b may have been switched. Our results suggest this to be the case.

quartz was quantitatively determined; and zeolite, feldspar, and illite were qualitatively estimated. Grain densities were also measured in the hope that a good correlation might allow rapid estimates of CO₂ content.

Prior to this study there was little quantitative data on the presence of CO₂ in Yucca Flat alluvium (see Table

1) and almost none on the distribution of calcite and dolomite.² It was clear that more data were needed to assess the role of carbonate minerals in the containment of underground nuclear explosions.

We are working on correlation of the data from this report with containment experience.

Sampling Methods

Samples were taken at the U. S. Geological Survey (USGS) Core Library in Mercury, Nevada. For core and bucket samples, a representative specimen of about a quart volume was taken. Sidewall core and cuttings were split, and half of the available materials was taken. If the cuttings volume was too small, a composite was made from several intervals.

Most of the sample depth-intervals were chosen to be near the planned detonation point of nuclear explosions. However, in some cases no sample existed for that depth or a better-quality sample was available a slight distance away.

In the ideal case a large representative sample would have been analyzed for each hole. However, there are few cores of

alluvium at NTS. After taking all core, sidewall core, and bucket (junk basket) samples available, we were forced to rely on cuttings samples for many drill holes. For example, two-thirds of the holes had only cuttings samples for the alluvium interval.

The common practice at NTS is to collect pint samples of drill cuttings at 10-ft sample intervals. These cuttings are then washed and the +30 mesh fraction is retained for geological observation. Thus, nearly all cuttings samples represent the greater-than-0.6-mm-size fraction of the original cuttings. Because fractionation is possible, the reliability of the cuttings samples can be questioned. This topic is discussed further on pp. 7-9.

Analytical Methods

Each bulk sample was crushed in an alumina jaw crusher. A 20-50 g portion was split from the bulk sample, pulverized to -100 mesh particle size in a tungsten-carbide rotary-plate pulverizer, and finally ground to -325 mesh in a tungsten-carbide ball mill.

The analyses of calcite, dolomite, and quartz were done in duplicate by x-ray diffractometry, using the internal standard method discussed in detail by Braun and Ramspott.⁴ To lessen the errors due to peak superposition, the peak maximum rather than the peak area was used. The

analytical precision at the 95% confidence level for duplicate measurements is approximately 5.6% of the amount present for quartz and 14% for calcite and dolomite. The detectability limits are approximately 1 wt% quartz, 0.5 wt% calcite, and 1 wt% dolomite.

A separate diffractometer scan from 4 to 50 deg 2θ was run prior to adding the internal standard. From this diffractogram, all phases present in detectable amounts were identified.

Because of the sensitivity of the method to particle size and degree of crystallinity

for calcite and dolomite, all samples were also chemically analyzed for CO_2 . CO_2 was evolved from the sample with acid, collected on Ascarite, and weighed. The detectability limit is about 0.02 wt% CO_2 , and the accuracy is 5% of the amount present. The calcite and dolomite values were adjusted to match the CO_2 analysis, keeping their ratio constant.⁴

The grain densities were determined on powdered material using a gas pycnometer modified to use a helium atmosphere. The precision of measurement is within ± 0.05 g/cc.

Discussion

GENERAL COMMENTS

The analytical results (see Appendix) show that most Yucca Flat alluvium has some carbonate minerals. However, in only 9 of 97 drill holes are there samples in which the CO_2 content exceeds 10 wt%.

Figure 1 is a histogram of the CO_2 content of the 119 alluvium samples. The mean CO_2 content is 4.77 wt%, but the median value is 3.60 wt% and the modal class is 0-1 wt%.

The calcite content of the same samples is illustrated in Fig. 2. The mean

Fig. 1. Histogram of CO_2 content of 119 alluvium samples from Yucca Flat.

Fig. 2. Histogram of calcite content of 119 alluvium samples from Yucca Flat.

Fig. 3. Histogram of dolomite content of 119 alluvium samples from Yucca Flat.

calcite content of all the samples is 5.9 wt%, using a value of zero for the seven samples in which calcite was not detected (less than 0.5 wt%). The mean of the measured values is 6.3 wt%. The median value for all samples is 2.5 wt%, and the modal class is 1-2 wt%.

Figure 3 shows the dolomite content of the alluvium samples. Dolomite was

not detected (less than 1 wt%) for 54 of the 119 samples. The mean, using a zero value for nondetection, is 4.5 wt%; but the mean of the 65 samples in which dolomite was detected is 8.2 wt%. The median value for all samples is 1.5 wt%, and the modal class is 0-1 wt%.

Figure 4 shows the cumulative relative frequency of CO_2 , dolomite, and calcite

Fig. 4. Cumulative relative frequency of CO₂, dolomite, and calcite in 119 alluvium samples from Yucca Flat.

in the 119 alluvium samples. The percentage of samples having less than a given amount of CO₂, dolomite, or calcite can be read directly from these curves.

Seven alluvium samples contain no detectable calcite, whereas 54 contain no detectable dolomite. Although the detectability limit for calcite is 0.5 wt%, compared with 1.0 for dolomite, the explanation for this distribution probably lies elsewhere. Of the samples 32% have between 1 and 2 wt% calcite, whereas only 10% have between 1 and 2 wt% dolomite. Calcite tends to be present in small amounts in nearly all samples; whereas dolomite is apparently absent from many samples. This is probably related to the fact that caliche (the near-surface cement typical of arid areas) contains calcite but not dolomite.

All samples with high dolomite content come from Area 2, whereas Area 9 is the source of high-calcite samples. The

Yucca Fault roughly coincides with the boundary between Areas 2 and 9, and the compositional differences between the areas may reflect both the fault and different sediment sources.

The tuff samples, as expected, contain no dolomite; and only a few contain small amounts of calcite. Surprisingly, however, the tuff is also relatively low in quartz. Although there is some indication of this low quartz in Ref. 2, it was not expected to be so marked for 14 different drill holes (see Appendix).

The only major phases detected in the samples, other than those reported in the Appendix, were kaolinite, montmorillonite, and silica glass. Kaolinite was present, with weak intensity, only in alluvium from the 2A emplacement hole. Montmorillonite was present, with strong intensity, only in tuff from the 2U exploratory hole. The presence of a silica glass phase in many of the samples was indicated by the broad diffraction maximum

centered near 24 deg 20. The glass content was notably high in the tuff samples from holes 9BB and 9I but was also detectable in many others, including alluvium samples.

The principal source rocks for Yucca Flat alluvium are limestone, dolomite, sandstone, argillite, and various types of tuff. The only minerals that can be traced to a specific source rock are zeolite (zeolitic tuff), calcite (limestone), dolomite (the rock dolomite), and silica glass (tuff).

The absence of kaolinite and montmorillonite might partly reflect the washing away of fine material in drill cuttings. However, those minerals were also absent from core, sidewall core, and bucket samples. Furthermore, studies by the USGS² also show the virtual absence of kaolinitic clay in Yucca Flat alluvium and the source tuffs (the tuffs contain mostly illite or locally montmorillonite).

VALIDITY OF CUTTINGS SAMPLES

As noted earlier, it is possible for cuttings samples to be fractionated during washing so that they no longer are a good sample of the rock in place. It should be pointed out, however, that a good cuttings sample may be better than a core for sampling material as coarsely heterogeneous as alluvium. It represents a considerably larger volume of rock material than most cores. The least satisfactory is sidewall core, which is only about 1-in. in diameter and 6-in. long. Several limestone pebbles in a sidewall core would have a great deal more effect than contamination of cuttings by caving from above. Cuttings samples are potentially

superior to other types of samples for chemical and mineralogic analysis.

There are two lines of evidence bearing on the validity of the washed cuttings samples: analysis of size fractions of total "undisturbed" samples and analysis of size fractions of "total cuttings" samples. There is a third case—a cuttings sample and sidewall sample from about the same depth were analyzed for 2AD instrument hole No. 1 (see Appendix). However, there is no reason to believe that samples that might be up to 10 ft apart will be similar. In 2AI, for example, considerable changes occur over 10-ft intervals.

The distribution of calcite, dolomite, quartz, and CO₂ as a function of size fraction of "undisturbed" samples is shown in Table 2. These six samples are geographically scattered, and they cover the common range of carbonate content. After disaggregation in a jaw crusher, the total sample was split and half was sieved on a 30-mesh screen (the size now used at the NTS Core Library). No total sample is shown for 9BG, because the total sample reported in the Appendix is from a different depth. There was not enough sample for an analysis of both bulk and sieved fractions. The data in Table 2 indicate that the error introduced by analyzing a +30 mesh fraction instead of the total sample may not be serious.

Disaggregation of a core in a jaw crusher may not give the same effect as the drilling process. Therefore, the distribution of CO₂ as a function of size fraction was investigated in samples of "total cuttings" collected by R. McArthur for J. Hill of Lawrence Radiation Laboratory's General Chemistry Division.

Table 2. Composition of samples as a function of size fraction.

Hole; depth (ft); sample type	Sample size fraction	CO ₂ (wt%)	Calcite (wt%)	Dolomite (wt%)	Quartz (wt%)
2A (752-62) Core	Total +30 mesh -30 mesh	7.26 7.34 5.84	7.6 8.7 6.1	8.2 7.4 6.6	26 25 14
2AI (620) Sidewall	Total +30 mesh -30 mesh	10.50 12.02 5.70	3.0 2.5 5.5	19.2 22.9 6.8	18 25 19
2DB (1186) Bucket	Total +30 mesh -30 mesh	2.77 3.21 1.14	1.9 2.5 2.0	4.0 4.4 0.5	27 32 13
2p (1330) Sidewall	Total +30 mesh -30 mesh	1.14 1.47 1.06	2.6 3.3 2.4	0 0 0	21 33 18
9AK (465) Sidewall	Total +30 mesh -30 mesh	3.91 5.16 3.40	8.9 11.7 7.7	0 0 0	8 11 7
9BG (450) Sidewall	+30 mesh -30 mesh	2.42 2.64	5.5 6.0	0 0	10 10

During drilling of Z-25 in Area 9ITS, "total cuttings" samples were taken by filling a 1-gal can with blooie line effluent. In seven samples separated on a 100 mesh screen, the +100 mesh fraction was over 85% of the sample. Although these samples showed some fractionation of CO₂ between the +100 and -100 size fraction, the +100 mesh fraction was so dominant that the CO₂ content of that fraction was nearly the same as that of the total sample.⁵ The data of Table 3 illustrate that for two samples separated on a 30 mesh screen, the +30 mesh fraction again adequately represents the CO₂ content of the total sample.

It can be concluded from the data in Tables 2 and 3 that the cuttings samples used in this study provide a usable indicator of the CO₂ content of the rock from

which they were derived. Far worse errors can be introduced by assuming that a particular sample represents other intervals higher or lower in the hole. Data relative to this point are given in the Appendix, which includes 23 drill holes

Table 3. CO₂ content as a function of size distribution for "total cuttings" from U9 ITS Z-25.

Sample depth (ft)	Sample size fraction	Wt% of fraction	CO ₂ (wt%)
160	+30 mesh	71.9	31.3
160	-30 mesh	28.1	10.5
160	Total	100	25.5
150	+30 mesh	86.1	37.7
150	30-100 mesh	6.7	14.8
150	-100 mesh	7.2	22.7
150	Total	100	35.1

for which two or more samples were analyzed. As noted before, the data from the 2AI emplacement hole are particularly instructive.

CORRELATION OF COMPOSITION AND GRAIN DENSITY

It was hoped that a good correlation might be found between grain density and carbonate content. Data for 156 samples of alluvium and tuff gave the following correlation coefficients:

- Density and CO₂ 0.409
- Density and calcite 0.131
- Density and dolomite 0.447
- Density and quartz 0.640.

In specific cases for which the variation in other minerals is limited, high correlations between density and a specific mineral are found. Figure 5 shows the correlation between dolomite and grain density for samples from 2AI, for which the correlation coefficient is 0.933.

Although grain density measurements will not give much information about a randomly chosen sample, they might be used together with chemical and x-ray calibrations to give a rapid analysis of

large numbers of samples from a single environment, as, for instance, the dolomite content in the 2AI hole. A grain density can be obtained in several minutes with a helium pycnometer, compared with hours for other types of analysis.

Fig. 5. Grain density vs weight-percent dolomite in samples from 2AI. The correlation coefficient for the curve

$$\begin{aligned} \text{grain density} = \\ 0.00537 (\text{wt\% dolomite}) + \\ 2.521 \\ \text{is } 0.933. \end{aligned}$$

Acknowledgments

P. Turner made the grain density determinations. J. Hill and L. Gregory of LRL Chemistry Department performed about two-thirds of the CO₂ analyses and Battelle Memorial Institute Analytical Laboratory, Columbus, Ohio, did the

others. J. Hill made available unpublished CO₂ analyses of samples from U9 ITS Z-25 hole. Much of the data in Table 1 was unpublished and was provided by the USGS Special Projects Branch from its files.

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MINERALOGIC COMPOSITION, CO₂ CONTENT, AND GRAIN DENSITY
OF NTS DRILL HOLE SAMPLES

HOLE	HOLE TYPE	SAMPLE TYPE	DEPTH INTERVAL FEET	GRAIN DENSITY G/CC	CARBON DIOXIDE WT %	CALCITE WT %	DOLOMITE WT %	QUARTZ WT %	ZEGLITE INTENSITY	FELDSPAR INTENSITY	ILLITE INTENSITY
-----ALLUVIUM-----											
2A	EMPLACEMENT	CORE	752 762	2.63	7.26	7.6	8.2	26.	WEAK	MEDIUM	WEAK
2AA	EMPLACEMENT	CUTTINGS	530 540	2.58	6.34	1.3	12.1	26.	WEAK	MEDIUM	WEAK
2AA	EMPLACEMENT	CUTTINGS	590 600	2.60	7.55	1.5	14.4	30.	WEAK	MEDIUM	WEAK
2AB	EMPLACEMENT	CUTTINGS	500 510	2.61	5.74	1.0	11.1	27.	TRACE	MEDIUM	WEAK
2AB	EMPLACEMENT	CUTTINGS	600 610	2.63	4.97	1.1	9.4	30.	WEAK	MEDIUM	WEAK
2AD	INSTRUMENT-1	CUTTINGS	760 770	2.60	5.05	1.5	9.2	35.	WEAK	MEDIUM	WEAK
2AD	INSTRUMENT-1	SIDEWALL	770 770	2.49	4.00	1.3	7.2	16.	WEAK	STRONG	WEAK
2AF	EMPLACEMENT	CUTTINGS	620 637	2.58	4.39	0.9	8.3	27.	WEAK	MEDIUM	WEAK
2AF	EMPLACEMENT	CUTTINGS	740 750	2.60	5.09	1.3	9.5	30.	WEAK	MEDIUM	WEAK
2AH	EMPLACEMENT	CUTTINGS	440 450	2.60	4.25	1.0	7.9	35.	WEAK	MEDIUM	WEAK
2AI	EMPLACEMENT	SIDEWALL	590 590	2.62	9.40	2.4	17.5	19.	WEAK	MEDIUM	WEAK
2AI	EMPLACEMENT	SIDEWALL	600 600	2.72	19.00	2.9	37.2	24.	WEAK	WEAK	WEAK
2AI	EMPLACEMENT	SIDEWALL	610 610	2.67	13.50	0.8	27.5	24.	NIL	MEDIUM	WEAK
2AI	EMPLACEMENT	SIDEWALL	620 620	2.64	10.50	3.0	19.2	18.	WEAK	MEDIUM	WEAK
2AI	EMPLACEMENT	SIDEWALL	630 630	2.59	5.20	1.9	9.1	26.	WEAK	MEDIUM	WEAK
2AI	EMPLACEMENT	SIDEWALL	640 640	2.52	3.42	4.2	3.3	14.	WEAK	MEDIUM	WEAK
2AI	EMPLACEMENT	SIDEWALL	650 650	2.53	9.20	10.6	9.5	20.	WEAK	MEDIUM	WEAK
2AI	EMPLACEMENT	SIDEWALL	670 670	2.63	13.10	3.5	24.2	14.	WEAK	MEDIUM	WEAK
2AK	EMPLACEMENT	CUTTINGS	560 580	2.63	9.17	1.0	18.3	24.	WEAK	MEDIUM	WEAK
2AL	INSTRUMENT-1	CORE	846 854	2.45	1.92	4.4	0.	16.	MEDIUM	MEDIUM	WEAK
2AN	EMPLACEMENT	CUTTINGS	710 720	2.71	20.10	0.9	41.3	22.	TRACE	WEAK	WEAK
2AN	EMPLACEMENT	CUTTINGS	810 820	2.68	10.20	1.6	19.9	30.	WEAK	WEAK	WEAK
2AP	EMPLACEMENT	CUTTINGS	710 730	2.58	3.85	1.4	6.8	35.	WEAK	MEDIUM	WEAK
2B	EMPLACEMENT	CORE	547 547	2.58	2.90	6.6	0.	32.	MEDIUM	WEAK	WEAK
2BD	EMPLACEMENT	CUTTINGS	900 910	2.62	2.20	2.5	2.3	41.	WEAK	MEDIUM	WEAK
2BD	EMPLACEMENT	CUTTINGS	1050 1060	2.67	5.35	5.8	5.9	46.	WEAK	WEAK	WEAK
2BE	EMPLACEMENT	BUCKET	1304 1305	2.46	0.54	1.2	0.	19.	WEAK	MEDIUM	TRACE
2BG	EMPLACEMENT	CUTTINGS	750 760	2.62	6.59	1.8	12.1	33.	WEAK	MEDIUM	WEAK
2BI	EMPLACEMENT	CUTTINGS	490 500	2.57	0.94	1.0	1.0	49.	WEAK	MEDIUM	WEAK
2BJ	EMPLACEMENT	CUTTINGS	560 570	2.65	0.34	0.8	0.	60.	TRACE	WEAK	WEAK
2BM	EMPLACEMENT	CUTTINGS	730 750	2.65	3.20	7.3	0.	52.	TRACE	WEAK	WEAK
2BU	EMPLACEMENT-1	CUTTINGS	560 570	2.68	0.35	0.8	0.	55.	WEAK	WEAK	WEAK
2BU	EMPLACEMENT-1	CUTTINGS	640 650	2.58	0.43	1.0	0.	36.	WEAK	MEDIUM	WEAK
2BU	EMPLACEMENT-2	CUTTINGS	640 650	2.62	0.23	0.5	0.	52.	WEAK	MEDIUM	WEAK
2BU	EMPLACEMENT-2	CUTTINGS	740 750	2.61	0.62	1.4	0.	27.	WEAK	MEDIUM	WEAK
2BU	EMPLACEMENT-2	CUTTINGS	620 630	2.49	1.38	3.1	0.	28.	MEDIUM	MEDIUM	WEAK
2CD	EMPLACEMENT	CUTTINGS	640 650	2.71	4.31	9.8	0.	58.	TRACE	NIL	WEAK
2CG	EMPLACEMENT	CUTTINGS	500 510	2.65	0.75	1.7	0.	64.	TRACE	WEAK	WEAK

Appendix

HOLE	HOLE TYPE	SAMPLE TYPE	DEPTH INTERVAL FEET	GRAIN DENSITY G/CC	CARBON DIOXIDE WT%	CALCITE WT %	DOLomite WT %	QUARTZ WT%	ZEOLITE INTENSITY	FELDSPAR INTENSITY	ILLITE INTENSITY
2CG	EMPLACEMENT	CUTTINGS	530 540	2.62	1.02	2.3	0.	68.	TRACE	NIL	WEAK
2DB	EMPLACEMENT	BUCKET	1186 1186	2.53	2.77	1.9	4.0	27.	WEAK	MEDIUM	WEAK
2DC	EMPLACEMENT-4	CUTTINGS	740 760	2.68	2.52	3.9	1.7	61.	NIL	NIL	WEAK
2DC	EMPLACEMENT-5	CUTTINGS	810 830	2.69	2.40	5.5	0.	60.	NIL	NIL	WEAK
2DE	EMPLACEMENT	CUTTINGS	1520 1530	2.62	2.32	2.6	2.5	46.	NIL	MEDIUM	WEAK
2DT	EMPLACEMENT	CUTTINGS	1250 1260	2.58	3.60	6.4	1.6	25.	NIL	MEDIUM	WEAK
2E	EMPLACEMENT	CUTTINGS	740 750	2.61	0.99	2.3	0.	48.	WEAK	MEDIUM	TRACE
2F	EMPLACEMENT	CUTTINGS	490 500	2.64	6.88	0.	14.4	44.	WEAK	MEDIUM	WEAK
2G	EMPLACEMENT	CORE	742 742	2.57	7.44	2.9	12.9	20.	WEAK	STRONG	WEAK
2H	EMPLACEMENT	CORE	540 548	2.55	2.02	1.6	2.7	37.	WEAK	MEDIUM	WEAK
2J	EMPLACEMENT	CUTTINGS	530 560	2.65	0.38	0.	0.8	55.	WEAK	MEDIUM	WEAK
2L	EMPLACEMENT	CUTTINGS	740 750	2.56	0.83	1.9	0.	38.	WEAK	MEDIUM	WEAK
2M	EMPLACEMENT	CUTTINGS	540 555	2.61	0.21	0.	0.	52.	WEAK	MEDIUM	WEAK
2N	INSTRUMENT-1	SIDEWALL	865 865	2.61	4.43	1.5	7.9	38.	WEAK	MEDIUM	WEAK
2P	INSTRUMENT-1	SIDEWALL	1330 1330	2.54	1.14	2.6	0.	21.	WEAK	MEDIUM	WEAK
2R	EMPLACEMENT	CUTTINGS	770 780	2.57	9.80	1.2	19.4	35.	WEAK	MEDIUM	WEAK
2R	EMPLACEMENT	CUTTINGS	870 890	2.66	5.99	1.5	11.2	25.	WEAK	MEDIUM	WEAK
2U	EMPLACEMENT	CUTTINGS	700 710	2.57	3.92	1.5	6.8	32.	WEAK	MEDIUM	WEAK
2U	EMPLACEMENT	CUTTINGS	800 820	2.59	3.90	1.8	6.5	30.	WEAK	MEDIUM	WEAK
2Y	EMPLACEMENT	CUTTINGS	700 710	2.62	3.86	1.5	6.7	36.	WEAK	STRONG	WEAK
2Y	EMPLACEMENT	CUTTINGS	800 820	2.57	4.48	2.1	7.5	31.	WEAK	MEDIUM	WEAK
3DK	EMPLACEMENT	CUTTINGS	550 550	2.40	1.00	0.	2.1	15.	WEAK	STRONG	TRACE
3DY	EMPLACEMENT	CUTTINGS	570 580	2.52	0.88	0.	1.8	22.	WEAK	MEDIUM	WEAK
3DY	EMPLACEMENT	CUTTINGS	600 610	2.54	1.41	1.5	1.5	22.	WEAK	MEDIUM	WEAK
3EM	EMPLACEMENT	CUTTINGS	1015 1025	2.52	1.46	3.3	0.	23.	WEAK	MEDIUM	WEAK
5A	EMPLACEMENT	CUTTINGS	570 580	2.59	0.70	1.6	0.	10.	WEAK	STRONG	TRACE
5B	EMPLACEMENT	CUTTINGS	620 640	2.53	0.68	1.5	0.	10.	TRACE	STRONG	TRACE
5K	EMPLACEMENT	CUTTINGS	820 835	2.72	1.86	4.2	0.	11.	WEAK	STRONG	WEAK
5K	EXPLORATORY	SIDEWALL	920 920	2.56	6.08	13.8	0.	14.	MEDIUM	MEDIUM	TRACE
9A	EMPLACEMENT	CUTTINGS	590 610	2.56	1.22	2.8	0.	15.	MEDIUM	MEDIUM	WEAK
9AA	EMPLACEMENT	CORE	740 750	2.43	0.58	1.3	0.	8.	WEAK	MEDIUM	TRACE
9AB	EMPLACEMENT	CORE	740 748	2.47	1.29	2.9	0.	9.	WEAK	MEDIUM	TRACE
9AC	EMPLACEMENT	CORE	430 438	2.43	0.88	2.0	0.	10.	MEDIUM	MEDIUM	NIL
9AH	EMPLACEMENT	CUTTINGS	685 695	2.60	6.00	11.8	1.7	19.	WEAK	MEDIUM	WEAK
9AL	EMPLACEMENT	CUTTINGS	755 760	2.46	1.11	2.5	0.	18.	MEDIUM	MEDIUM	WEAK
9AP	EMPLACEMENT	CUTTINGS	650 660	2.48	1.09	2.5	0.	13.	WEAK	STRONG	TRACE
9AQ	EMPLACEMENT	CUTTINGS	480 490	2.58	3.25	7.4	0.	12.	TRACE	MEDIUM	WEAK
9AR	EMPLACEMENT	SIDEWALL	465 465	2.47	3.91	8.9	0.	8.	WEAK	MEDIUM	NIL
9AR	EMPLACEMENT	SIDEWALL	515 515	2.54	7.18	16.3	0.	9.	WEAK	MEDIUM	WEAK
9AT	EMPLACEMENT	CUTTINGS	540 550	2.40	0.46	1.0	0.	10.	MEDIUM	MEDIUM	TRACE
9AU	EMPLACEMENT	CUTTINGS	390 400	2.59	17.50	37.5	2.1	9.	WEAK	MEDIUM	WEAK

HOLE	HOLE TYPE	SAMPLE TYPE	DEPTH INTERVAL FEET	GRAIN DENSITY G/CC	CARBON DIOXIDE WT %	CALCITE WT %	DOLCHITE WT%	QUARTZ WT%	ZEOLITE INTENSITY	FELDSPAR INTENSITY	ILLITE INTENSITY
9AV	EMPLACEMENT	CUTTINGS	450 460	2.50	6.56	10.2	4.3	8.	TRACE	MEDIUM	NIL
9AV	EMPLACEMENT	CUTTINGS	540 550	2.51	0.99	2.3	0.	16.	WEAK	MEDIUM	TRACE
9AM	INSTRUMENT-1	SIDEWALL	525 525	2.53	5.63	12.8	0.	7.	WEAK	MEDIUM	TRACE
9B	EMPLACEMENT	CUTTINGS	617 627	2.53	1.26	0.8	1.9	30.	WEAK	MEDIUM	WEAK
9BA	EMPLACEMENT	CUTTINGS	460 470	2.57	19.90	45.3	0.	11.	WEAK	MEDIUM	WEAK
9BD	INSTRUMENT-1	CORE	404 408	2.52	4.43	8.4	1.5	9.	NIL	MEDIUM	WEAK
9BF	EMPLACEMENT	CUTTINGS	390 400	2.52	2.39	4.0	1.3	9.	TRACE	STRONG	WEAK
9BG	INSTRUMENT-1	SIDEWALL	460 460	2.50	4.84	11.0	0.	9.	NIL	MEDIUM	WEAK
9BM	EMPLACEMENT	CUTTINGS	470 480	2.50	4.92	11.2	0.	10.	NIL	MEDIUM	WEAK
9BU	EMPLACEMENT	CUTTINGS	650 660	2.52	3.28	7.5	0.	14.	TRACE	MEDIUM	WEAK
9BY	EMPLACEMENT	CUTTINGS	300 310	2.47	0.52	1.2	0.	14.	MEDIUM	STRONG	TRACE
9C	EMPLACEMENT	CUTTINGS	590 600	2.47	0.08	0.	0.	27.	NIL	MEDIUM	NIL
9CE	INSTRUMENT-1	CORE	1374 1382	2.48	1.48	3.4	0.	5.	NIL	MEDIUM	WEAK
9CF	INSTRUMENT-2	CORE	1196 1204	2.40	0.01	0.	0.	5.	NIL	MEDIUM	NIL
9CF	EMPLACEMENT	CUTTINGS	630 640	2.65	27.50	60.1	2.2	6.	TRACE	WEAK	TRACE
9D	INSTRUMENT-1	CORE	840 847	2.43	2.08	1.5	3.0	14.	MEDIUM	MEDIUM	TRACE
9G	EMPLACEMENT	CUTTINGS	630 640	2.59	18.09	38.9	2.1	14.	TRACE	WEAK	TRACE
9K	EMPLACEMENT	CUTTINGS	630 640	2.50	3.60	6.5	1.5	18.	TRACE	MEDIUM	TRACE
9M	EMPLACEMENT	CUTTINGS	700 710	2.41	2.94	6.7	0.	15.	MEDIUM	MEDIUM	WEAK
9N	EMPLACEMENT	CORE	450 450	2.51	12.80	29.1	0.	5.	WEAK	MEDIUM	TRACE
9Q	EMPLACEMENT	CUTTINGS	570 590	2.47	0.92	2.1	0.	21.	MEDIUM	MEDIUM	WEAK
9R	EMPLACEMENT	CORE	545 555	2.45	0.70	1.6	0.	10.	WEAK	MEDIUM	NIL
9U	EMPLACEMENT	CUTTINGS	510 530	2.55	14.30	26.1	5.9	10.	WEAK	MEDIUM	TRACE
9U	EMPLACEMENT	CORE	570 580	2.55	11.20	16.4	8.3	10.	TRACE	MEDIUM	TRACE
9W	EMPLACEMENT	CORE	590 600	2.49	1.89	4.3	0.	9.	WEAK	MEDIUM	WEAK
9X	EMPLACEMENT	CUTTINGS	670 680	2.56	7.83	17.8	0.	18.	WEAK	MEDIUM	WEAK
9Z	EMPLACEMENT	CORE	750 750	2.48	1.46	3.3	0.	9.	TRACE	MEDIUM	TRACE
10A	EMPLACEMENT	CUTTINGS	840 860	2.63	2.97	1.7	4.6	48.	WEAK	WEAK	WEAK
10AD	EMPLACEMENT	CUTTINGS	290 300	2.76	2.11	2.5	2.1	26.	WEAK	MEDIUM	WEAK
10AJB	EMPLACEMENT	BUCKET	554 556	2.52	5.60	7.6	4.8	7.	TRACE	MEDIUM	TRACE
10AJB	EMPLACEMENT	BUCKET	651 654	2.59	7.54	4.4	11.8	21.	WEAK	MEDIUM	WEAK
10AJD	EMPLACEMENT	BUCKET	930 930	2.53	14.50	31.2	1.6	4.	NIL	MEDIUM	WEAK
10AM	EMPLACEMENT-1	BUCKET	660 660	2.52	6.02	13.7	0.	24.	WEAK	MEDIUM	WEAK
10DS	INSTRUMENT-1	SIDEWALL	577 577	2.50	7.96	15.8	2.1	5.	NIL	STRONG	WEAK
10F	EMPLACEMENT	CUTTINGS	990 1010	2.46	0.83	1.9	0.	8.	TRACE	STRONG	NIL
10G	EMPLACEMENT	CORE	990 998	2.46	4.10	9.3	0.	6.	TRACE	MEDIUM	TRACE
10M	EMPLACEMENT	CUTTINGS	670 690	2.52	1.37	3.1	0.	13.	WEAK	STRONG	WEAK
10W	EMPLACEMENT	CUTTINGS	650 660	2.65	3.60	3.2	4.6	30.	WEAK	MEDIUM	WEAK
10X	EMPLACEMENT	CUTTINGS	850 860	2.56	5.66	8.0	4.5	19.	WEAK	MEDIUM	WEAK
10Z	EMPLACEMENT	CUTTINGS	520 540	2.64	1.55	1.6	1.8	28.	TRACE	MEDIUM	WEAK
AVERAGE				2.56	4.77	5.9	4.5	24.			

HOLE	HOLE TYPE	SAMPLE TYPE	DEPTH FEET	DENSITY G/CC	CARBON DIOXIDE WT %	CALCITE WT %	DOLomite WT %	QUARTZ WT %	ZECLITE INTENSITY	FELDSPAR INTENSITY	ILLITE INTENSITY
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TUFF

2CC	EMPLACEMENT	CUTTINGS	500	510	2.59	0.02	0.0	0.0	25.0	NIL	STRONG	WEAK
2CK	EMPLACEMENT	CUTTINGS	760	770	2.49	0.08	0.0	0.0	15.0	NIL	STRONG	WEAK
2K	EMPLACEMENT	CUTTINGS	1160	1165	2.51	0.27	0.0	0.0	0.0	WEAK	STRONG	WEAK
2U	EMPLACEMENT	CUTTINGS	1310	1320	2.60	0.02	0.0	0.0	14.0	NIL	STRONG	NIL
2U	EXPLORATORY	SIDEMALL	600	600	2.36	0.06	0.0	0.0	3.0	NIL	STRONG	NIL
2U	EXPLORATORY	SIDEMALL	700	700	2.27	0.18	0.0	0.0	0.0	NIL	STRONG	NIL
2U	EXPLORATORY	SIDEMALL	750	750	2.22	0.71	1.6	0.0	3.0	NIL	STRONG	NIL
2U	EXPLORATORY	SIDEMALL	800	800	2.34	0.46	1.0	0.0	15.0	WEAK	STRONG	NIL
2U	EXPLORATORY	SIDEMALL	850	850	2.30	0.27	0.6	0.0	1.0	NIL	STRONG	NIL
98B	EMPLACEMENT	SIDEMALL	705	705	2.38	0.0	0.0	0.0	1.0	NIL	STRONG	TRACE
98B	EMPLACEMENT	SIDEMALL	715	715	2.38	0.0	0.0	0.0	1.0	NIL	STRONG	TRACE
98B	EMPLACEMENT	SIDEMALL	725	725	2.40	0.0	0.0	0.0	2.0	NIL	STRONG	WEAK
98B	EMPLACEMENT	SIDEMALL	735	735	2.35	0.0	0.0	0.0	5.0	NIL	STRONG	NIL
98B	EMPLACEMENT	SIDEMALL	745	745	2.41	0.07	0.0	0.0	2.0	NIL	STRONG	NIL
98B	EMPLACEMENT	SIDEMALL	755	755	2.34	0.0	0.0	0.0	2.0	NIL	STRONG	NIL
98B	EMPLACEMENT	SIDEMALL	765	765	2.42	0.0	0.0	0.0	6.0	NIL	STRONG	NIL
98B	EMPLACEMENT	SIDEMALL	775	775	2.36	0.0	0.0	0.0	5.0	NIL	STRONG	NIL
98B	EMPLACEMENT	SIDEMALL	785	785	2.36	0.0	0.0	0.0	6.0	NIL	STRONG	NIL
98C	EMPLACEMENT	SIDEMALL	670	670	2.41	0.06	0.0	0.0	8.0	NIL	STRONG	NIL
98D	INSTUMENT-1	CORE	600	608	2.53	0.02	0.0	0.0	15.0	NIL	STRONG	WEAK
98E	INSTUMENT-1	CORE	667	675	2.53	0.09	0.0	0.0	5.0	NIL	STRONG	WEAK
98S	EMPLACEMENT	CORE	720	728	2.59	0.69	1.6	0.0	0.0	NIL	STRONG	WEAK
9C	EMPLACEMENT	CUTTINGS	670	680	2.51	0.23	0.5	0.0	2.0	NIL	STRONG	WEAK
9I	RAD.CHEM.-1	CORE	600	600	2.30	0.14	0.0	0.0	1.0	MEDIUM	STRONG	NIL
9I	RAD.CHEM.-1	CORE	850	850	2.41	0.24	0.0	0.0	1.0	NIL	STRONG	WEAK
9X	EMPLACEMENT	CORE	760	760	2.57	0.02	0.0	0.0	20.0	TRACE	STRONG	TRACE
10C	INSTUMENT-1	CORE	1665	1665	2.53	0.05	0.0	0.0	0.0	NIL	STRONG	WEAK

AVERAGE

2.42 0.14 0.2 0. 6.

-----DOLomite-----

2CE	EMPLACEMENT	CORE	1176	1182	2.86	46.80	1.8	96.4	0.0	NIL	NIL	NIL
10B	EMPLACEMENT	CORE	1319	1319	2.86	47.30	0.6	98.6	0.0	NIL	NIL	NIL
AVERAGE					2.86	47.05	1.2	97.5	0.0