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RED AND GRAY CLAY UNDERLYING ORE-BEARING SANDSTONE OF THE MORRISON FORMATION IN WESTERN COLORADO

By
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RED AND GRAY CLAY UNDERLYING ORE-BEARING SANDSTONE OF THE MORRISON FORMATION IN WESTERN COLORADO

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ABSTRACT

A preliminary study of the clays underlying the ore-bearing sandstone of the Morrison formation, Colo., has tentatively identified the chief clay mineral as hydrous mica. Complete and partial chemical analyses show that the red clay contains more total iron and ferric iron than the gray clay. Spectrographic analyses of minor constituents show no significant difference between the red and gray except in iron content. Quartz and carbonate have a wide range in quantity that is not related to the color of the clay. Insufficient evidence is available from these specimens to indicate whether the gray altered from the red clay.

INTRODUCTION

A preliminary investigation of red and gray clay underlying the ore-bearing sandstone of the Morrison formation was undertaken for the purposes of determining the characteristics of and differences between the red and gray clays and of finding evidence bearing on the possible alteration of red to gray color. The reason for the investigation is that the presence of considerable gray ("altered") mudstone immediately below the ore-bearing sandstone is "probably the most useful guide in recognizing ground favorable for ore deposits,"1/ and, therefore, information about the clays may be of value in solving the problem of origin of the ore.

The work has been preliminary in that several methods and techniques for study of the clay and for the separation and identification of constituent minerals were tried on a small number of samples with an aim to select the most valuable methods for further study.

Acknowledgments

Thanks are extended to the following members of the Geological Survey: L. R. Stieff, who collected the samples, E. A. Cisney for X-ray powder patterns, A. M. Sherwood and R. Meyrowitz for chemical analyses, G. T. Faust for differential thermal analyses, M. D. Foster for base-exchange determination, C. L. Waring for spectrographic analyses, E. Z. Knudson for electron microscope examination, and R. P. Fischer and David Gallagher who very kindly read and criticized the manuscript.

SAMPLES

Material from the base of the ore-bearing sandstone at Dynamite mine, Bitter Creek group, Montrose County, Colo., consisted of red

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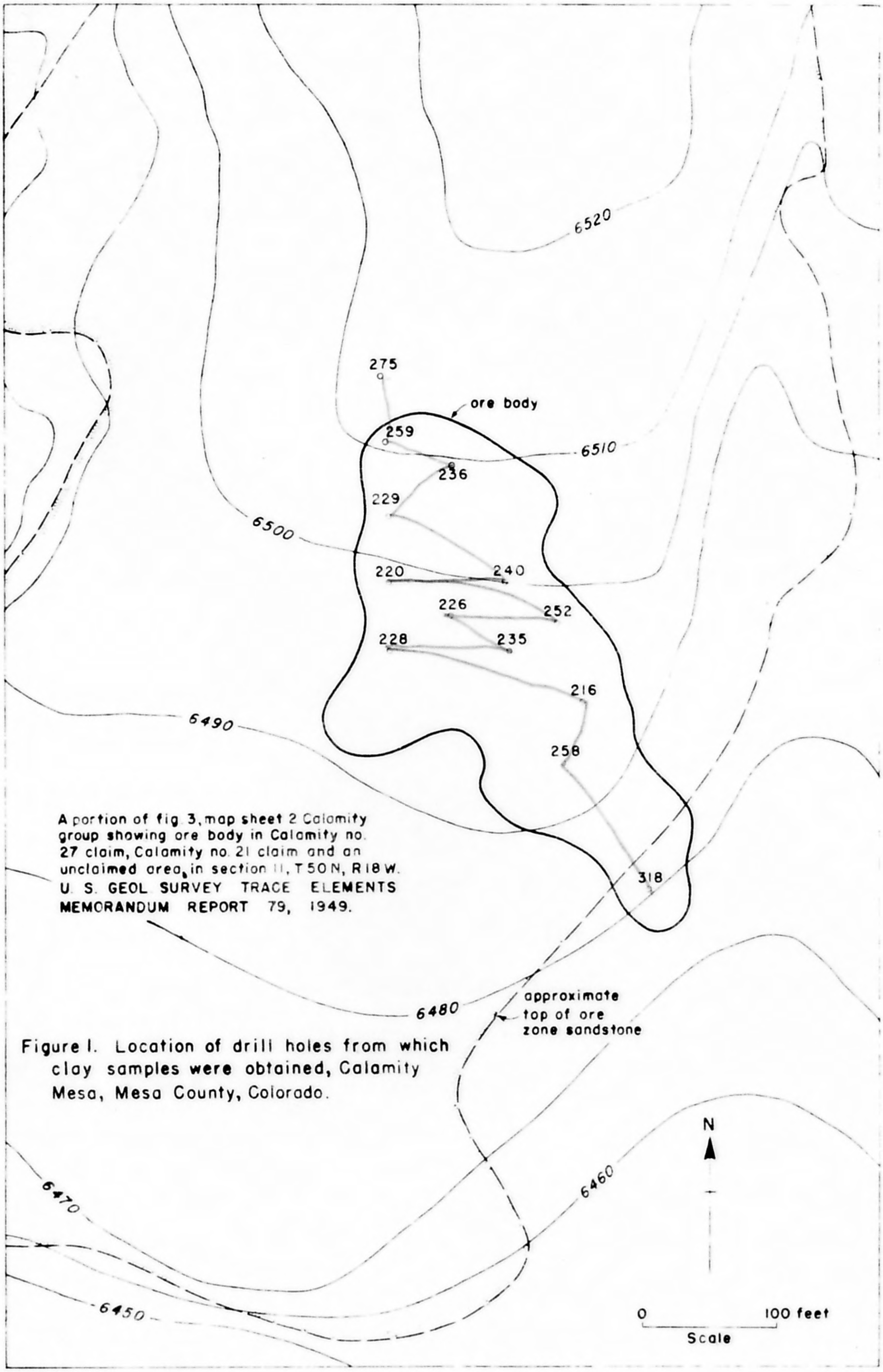
1/ Fischer, R. P., and Blackman, D., Geologic guides to carnotite deposits on the Colorado Plateau: U. S. Geol. Survey Trace Elements Investigations Rept. 86, August 1949.

and gray clays with an irregular boundary between them. The 11 gray and 10 red clay samples from Calamity Mesa, Mesa County, Colo., were parts of 1-inch drill cores from thirteen holes through or near the ore body (figs. 1 and 2). The ore-bearing sandstone is 58 to 68 feet below the surface of the Mesa; the clay samples consisted of seven gray and five red clays from a zone 8 to 18 feet below the ore-bearing sandstone and four gray and five red clays from another zone 45 to 60 feet below the ore. In some holes only gray or only red clay was recovered in the drilling. In six of the eight holes where both red and gray clay were recovered the gray occurs on top of the red clay. In general, drilling stopped in the first red clay below the ore body, but it can be seen in figure 2 that two clay zones exist and that in drill holes only 50 feet apart there may be as much as 45 feet difference in altitude of the bottoms of the holes.

PETROGRAPHIC DESCRIPTION

Both red and gray clays from Calamity Mesa are thin-bedded; the grain size differs from layer to layer ranging from clay particles with diameters of a few microns to sandy clay with quartz grains up to 0.5 mm diameter. After the samples were ground to pass 100 mesh, the colors were, according to the Rock Color Chart (distributed by the National Research Council, 1948) light gray, N7, to light greenish gray, 5 GY 8/1, and pale red, 10 R 6/2, with some grayish orange pink, 5 YR 7/2, and pale brown, 5 YR 5/2. The clay with little or no carbonate cement is friable and easily disaggregated in water, whereas that containing up to 15 percent of carbonate commonly is much less friable and after two weeks in water was only partly disaggregated.



A portion of fig. 3, map sheet 2 Calamity group showing ore body in Calamity no. 27 claim, Calamity no. 21 claim and an unclaimed area, in section 11, T 50 N, R 18 W. U. S. GEOL. SURVEY TRACE ELEMENTS MEMORANDUM REPORT 79, 1949.

Figure 1. Location of drill holes from which clay samples were obtained, Calamity Mesa, Mesa County, Colorado.

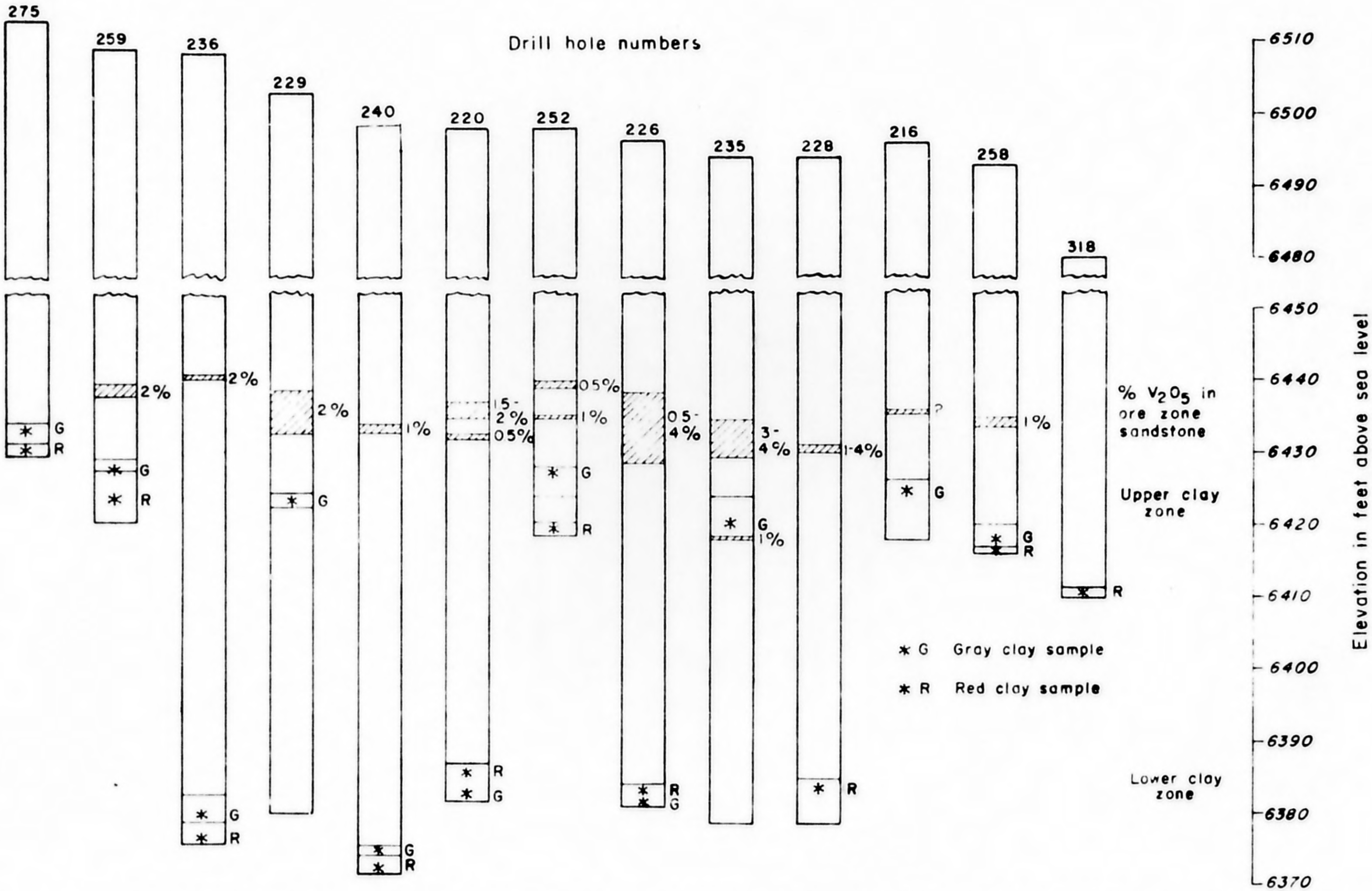


Figure 2.— Depth of clay samples and relation to ore sandstone, plotted from drill logs, Calamity Mesa, Mesa County, Colorado. (Location of drill holes shown in figure 1.)

The chief minerals at both localities are a clay mineral, quartz, and carbonate (probably in part dolomite and in part calcite). Traces of feldspar, biotite, chlorite, tourmaline, spinel, and zircon are present.

Chemical analyses, X-ray powder patterns, differential thermal analyses, base-exchange determination, petrographic and electron microscope study of the Bitter Creek clay samples strongly suggest that the chief clay mineral is hydrous mica. It is hoped that, when this clay mineral can be separated from some larger samples and purified, the identification will be positive. X-ray patterns showed quartz, hydrous mica, and dolomite; although much larger in quantity the hydrous mica gives a much weaker pattern than the quartz. The base exchange is near the lower limit for hydrous mica and is far below that for montmorillonite. The mean index of refraction is within the range of hydrous mica and above that of montmorillonite. In the electron microscope the clay grains are seen to be flaky; no rod- or lath-shaped grains have been observed. The differential thermal analyses show a mixture of several minerals: quartz, probably hydrous mica, and a small amount of carbonate. The chemical analyses (table 1) have an appropriate amount of potash for hydrous mica. Comparison of 21 Calamity Mesa samples with the 2 from Bitter Creek by means of the spectrograph (table 2) and the petrographic and electron microscopes showed them to be similar.

Dolomite was identified in two X-ray patterns. About three-fourths of the clay samples effervesce in cold dilute hydrochloric acid which indicates the presence of calcite, and in several samples the index of refraction of rhombohedral cleavage fragments also indicated calcite.

Determining the proportion of quartz (or free silica) and clay mineral in the rock is a problem that has not been solved satisfactorily for all specimens. The relative amount of sand-size quartz can be measured easily in a traverse of a thin section with a Wentworth stage. Sandy clay from Calamity Mesa contained up to 40 percent quartz sand, mostly subangular. If a sandy clay ground to between 50 and 100 mesh is run through the Frantz magnetic separator, a fair separation of the quartz sand (perhaps 85 percent) is obtained. To determine the proportion of quartz and clay minerals in a fine-grained rock several attempts were made to dissolve the clay and obtain a pure quartz residue. Each residue was checked spectrographically to see if any clay constituent remained. The chemists who made the analyses thought that the smallest quartz particles had begun to dissolve before the last of the clay was removed. Separation by heavy liquids, sedimentation, and centrifuging of the small samples available for this preliminary study did not give large enough or clean enough fractions of fine-grained quartz and clay to be useful.

CHEMICAL COMPOSITION OF THE CHIEF CLAY MINERAL

Several attempts have been made to calculate the composition of the chief clay mineral from the chemical analyses of the red and gray clay from Bitter Creek (table 1). An estimate of 10 percent quartz and up to 5 percent calcite was indicated by study of these clays in

Table 1.--Chemical analyses of red and gray clays from Bitter Creek, Montrose County, Colo., and of illite, Goose Lake, Ill.

GRAY CLAY

	Rock analysis 1/	Recalculated analyses			
		-10% quartz - 5% calcite	-15% quartz - 5% calcite	-20% quartz - 5% calcite	-30% quartz - 5% calcite
SiO_2	65.48	65.08	62.90	60.45	54.38
Al_2O_3	8.41	9.87	10.48	11.18	12.89
Fe_2O_3	2.44	2.86	3.04	3.24	3.74
FeO	0.70	0.82	0.87	0.93	1.07
MgO	4.07	4.59	4.87	5.19	5.99
CaO	2.58	--	--	--	--
Na_2O	0.20	0.24	0.25	0.27	0.31
K_2O	5.63	6.60	7.02	7.48	8.63
TiO_2	0.59	0.69	0.74	0.78	0.90
V_2O_5	0.07	0.08	0.09	0.09	0.11
CO_2	2.20	--	--	--	--
Ign. loss	7.82	9.17	9.74	10.39	11.98
	100.19	100.00	100.00	100.00	100.00

RED CLAY / ILLITE 3/

	Rock analysis 2/	Recalculated analyses			Illite 3/
		-10% quartz -3.2% calcite	-15% quartz -3.2% calcite	-20% quartz -3.2% calcite	
SiO_2	61.76	59.50	57.04	54.24	52.79
Al_2O_3	10.62	12.21	12.96	14.00	24.99
Fe_2O_3	5.51	6.34	6.72	7.16	4.68
FeO	0.97	1.12	1.18	1.26	1.10
MgO	4.11	4.73	5.01	5.34	2.70
CaO	2.38	0.67	0.71	0.76	0.09
Na_2O	0.09	0.10	0.11	0.12	0.20
K_2O	6.02	6.92	7.34	7.82	5.86
TiO_2	0.58	0.62	0.71	0.76	--
V_2O_5	0.07	0.08	0.09	0.09	--
CO_2	1.38	--	--	--	--
Ign. loss	6.66	7.66	8.13	8.65	7.14
	100.15	100.00	100.00	100.00	99.55

1/ Analyst: A. M. Sherwood
2/ Analyst: A. M. Sherwood
3/ Analyzed under supervison of O. W. Rees, in Grim, R. E., and Bradley W. F., A unique clay from the Goose Lake, Illinois, area: Illinois Geol. Survey Rept. Invs. 53, p. 11, 1939.

thin sections and immersion liquids. Chemical determination of CO_2 indicated that the gray clay contains 5 percent calcite and the red clay 3.2 percent calcite. Recalculated on this basis (column 2, table 1), the analyses are high in silica. Approximately 16 percent quartz residue was left when the clay had been decomposed and removed by hydrofluosilicic acid treatment. The amount of quartz in the rock could have been greater than the 16 percent residue because some quartz may have dissolved before all the clay was decomposed.

If it is assumed (1) that the aluminum, magnesium, and iron are in the octahedral layer, (2) that no aluminum is with the silicon in the tetrahedral layer, and (3) that some of the ferric iron in the red clay is hematite, the amount of excess silica would be 28 percent for the gray clay and 19.7 percent for the red clay. Column 5, table 1 for the gray, and column 4, table 1, for the red were compared with published analyses of illite 2/ (hydrous mica). The chief difference is that the clay mineral from Bitter Creek has less alumina and more magnesia than illite. However, its composition seems to be within the range of the hydrous mica group.

If the clay mineral from a much larger sample could be purified by means of the infrasizer, by decanting, and by centrifuging, the chemical composition could be determined with more certainty than in this preliminary study.

2/ Grim, R. E., and Bradley, W. F., A unique clay from the Goose Lake, Illinois, area: Illinois Geol. Survey Rept. Invs. 53, p. 11, 1939.

COMPARISON OF RED AND GRAY CLAYS

The only significant difference that has been found between the red and gray clays, other than color, is the difference in total iron and state of oxidation of the iron (tables 1 and 2). Both at Bitter Creek and Calamity Mesa the total iron and ferric iron are considerably higher in the red than in the gray clay. At Bitter Creek the ferrous iron also is higher in the red than in the gray, but at Calamity Mesa the gray (average of 6 samples) is higher in ferrous iron than the red clay (average of 8 samples).

The average of the radiometric counts on all the clay samples indicates 0.002 percent equivalent uranium. Althought the count for the gray clay (0.0022 percent equivalent uranium) averages slightly higher than for the red clay (0.0018 percent equivalent uranium), the difference is not significant because it is less than the possible analytical error.

The analyses show that the uranium content averages 0.0014 percent for the gray and 0.0017 percent for the red clay. The variation in the order of abundance of major constituents shown in the semiquantitative spectrographic analysis (table 3) is due to different amounts of calcite cement as well as difference in iron content. No relation between minor elements and the color of the clay is apparent.

The iron oxide pigment in the red clay is so fine grained that even at the high magnification of the electron microscope it appears as a cloudy streak rather than as distinct grains. No difference between the clay mineral of the red and gray clays was observed in either the electron or petrographic microscope.

Table 2.--Partial chemical analyses of red and gray clays from Calamity Mesa, Colo.

Samples from upper clay zone		Total Fe as Fe_2O_3	FeO	Fe_2O_3	TiO_2	V_2O_5 2/
No. 275 1/	gray	2.00	0.65	1.28	0.51	0.02
	red	3.86	0.88	2.88	0.58	0.03
No. 259	gray	2.06	0.81	1.15	0.36	0.02
	red	3.75	0.85	2.81	0.56	0.02
No. 252	gray	3.57	1.38	1.83	0.58	0.04
	red	3.63	0.38	3.21	0.63	0.06
No. 258	gray	2.71	0.83	1.89	0.50	0.02
	red	5.00	1.35	3.50	0.57	0.04
Averages of samples						
Upper gray (average of 5 samples)		2.67	1.00	1.53	0.49	0.03
Upper red (average of 5 samples)		4.55	0.82	3.66	0.59	0.04
Lower gray (1 sample)		3.54	0.85	2.38	0.56	0.04
Lower red (average of 3 samples)		3.57	0.57	2.95	0.50	0.04
Average of 6 gray clays		2.82	0.98	1.67	0.50	0.03
Average of 8 red clays		4.18	0.63	3.39	0.56	0.04

Analyst: A. M. Sherwood

1/ Location of drill holes and samples shown in figures 1 and 2.
2/ The differences in V_2O_5 are not significant because the limit of error of the analytical method is ± 0.01 percent.

Table 3.--Semiquantitative spectrographic analysis of red and gray clays from Bitter Creek and Calamity Mesa, Colo., showing order of abundance of elements

Semiquantitative spectrographic brackets (percent)	Bitter Creek		Calamity Mesa			
	gray	red	Upper gray 1/	Upper red 2/	Lower gray 3/	Lower red 4/
Over 10.0	Si	Si	Si	Si	Si	Si
1.0 - 10.0	Al	Al	Al	Al	Al	Ca
	Mg	Fe	Ca	Fe	Ca	Al
	Fe	Mg	Fe	Ca	Fe	Fe
	K	K	K	K	K	K
	Ca	Ca			Mg	Mg
0.1 - 1.0	Ti	Ti	Mg	Mg	Na	Ti
	Zr	Na	Na	Ti	Ti	Na
	Na	Zr	Ti	Na	Sr	Sr
	Sr	Sr	Sr	Sr		
				Zr		
0.01 - 0.1	Ba	Ba	Zr	Ba	Zr	Zr
	V	V	Mn	Mn	Ba	Mn
	Cr	Cr	Ba	Cr	Mn	Ba
	Mn	Mn	Cr	Ni	Cr	Cr
	Sn	Cu	V	V	V	V
	Cu	Ni	Ni		Ni	
0.001 - 0.01	B	B	Cu	Cu	Cu	Ni
	Ni		B	B	B	Cu
			Pb			B
						Pb

Analyst: C. L. Waring

1/ Average of 7 gray clays from upper zone
2/ Average of 5 red clays from upper zone
3/ Average of 4 gray clays from lower zone
4/ Average of 5 red clays from lower zone

Note: The following elements were looked for but if present are in quantities below the limiting values given in percentages: 10, Rb; 1, Cs, Tl; 0.1, As, Ce, Ge, Hg, La, P, Re, Sc, Th, U, W; 0.01, Cb, Cd, Nd, Pt, Ta; 0.001, Ag, Be, Bi, Co, Ir, Mo, Sb, Y, Zn.

The differential thermal analyses, the base-exchange determination, and X-ray patterns show no difference between the red and gray clays.

AGE RELATIONS OF RED AND GRAY CLAYS

Inasmuch as very few samples showed the contact between red and gray clay no general conclusions concerning the nature of the contact and the problem of whether the gray has been altered from the red clay are justified from the preliminary study.

Only one sample, consisting of many small fragments of clay from Bitter Creek, showed a fairly sharp color boundary cutting across bedding planes. Although in this sample one color may have altered to the other, the thin section and the small rock fragments do not give evidence as to which was the original color. The chemical analyses (table 1) indicate that if the red were to change to gray, ferric iron and alumina would have to be removed and silica added.

The samples from drill hole number 258, Calamity Mesa, consist of gray clay directly overlying red clay and show a transitional zone of about 1/2 inch from the gray to the red. Table 2 shows that the red clay has much more total iron than the gray.

The sample of gray clay from drill hole number 252, Calamity Mesa, contains nearly as much total iron (table 2) as the sample of red clay that occurs 7 feet deeper. The red clay is separated from the gray by 3.4 feet of sandstone. In these samples the color is related to the state of oxidation of the iron, but there is no proof that the gray clay originally was red.

PLAN FOR FURTHER STUDY

The plan for further study is to make a positive identification of the clay mineral (or minerals) and to determine, if possible, whether part or all of the gray clay has been altered from red clay and by what process. Inasmuch as the gray clay is considered an important guide to ore an attempt will be made to find some genetic relationship between the color of the clay and the ore mineralization. It is proposed that chemical experiments be made in the laboratory to change the color of red clay to gray and vice versa.

A special effort will be made to select samples of clay from close beneath ore bodies in mines where the field relations can be observed and where large samples can be obtained. It is important to try to distinguish between gray clays that have been altered from red and those that have been gray since deposition or soon after. If pairs of red and gray clays can be obtained from the same stratigraphic horizon with equal (or nearly equal) "total iron" content, it is expected that a significant difference in the ratio of the iron oxides would be found between the red and gray clays.

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