UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

A STUDY OF THE MINERALOGY AND LITHOLOGY OF CUTTINGS FROM THE U.S. BUREAU OF RECLAMATION MESA 6-2 DRILLHOLE, IMPERIAL COUNTY, CALIFORNIA, INCLUDING COMPARISONS WITH THE MESA 6-1 DRILLHOLE

By Reba B. Fournier

Open-File Report 76-88

Menlo Park, California

February 1976

CONTENTS

ILLUSTRATIONS

TABLES

A STUDY OF THE MINERALOGY AND LITHOLOGY OF CUTTINGS FROM THE U.S. BUREAU OF RECLAMATION MESA 6-2 DRILLHOLE, IMPERIAL COUNTY, CALIFORNIA, INCLUDING COMPARISONS WITH THE MESA 6-1 DRILLHOLE

By Reba B. Fournier

ABSTRACT

The Mesa 6-2 drillhole penetrates 6,000 feet of sediments in Imperial County, California. The cuttings material from the upper part of the drillhole is chiefly unconsolidated mud and silt. Soft siltstone fragments occur at about 1,400 feet and increase in amount down to 2,400 feet. Some pebbles are found above 2,400 feet, but the pebble-rich horizons are less distinctive than the pebble zone in the Mesa 6-1 drillhole. Below 2,400 feet, cuttings are composed of about two-thirds siltstone and one-third sandstones, ranging from very fine to very coarse sand, plus loose sand grains. Although below 2,400 feet there is no systematic change in color of siltstones, grain size, or cementation with depth, horizons composed predominantly of loose sand are more common at deeper levels. Fragments of igneous and metamorphic rocks are less common than in the Mesa 6-1 drillhole.

Quartz, calcite, K-feldspar, plagioclase (albite), illite, and mixed layer clays are identified by X-ray diffractograms of whole-rock samples throughout the hole. Chlorite occurs in all samples from below 2,100 feet, and probably also occurs at shallower depths.

In most siltstones, montmorillonite occurs only down to the interval 2,200-2,300 feet, but in the buff siltstone it is found to the bottom of the drillhole. Kaolinite occurs at least down to 4,700 feet. Dolomite is found down to at least 5,970 feet, but is generally absent from horizons composed mostly of loose sand. Pyrite occurs in many samples. No zeolites, ankerite, or amorphous sulfur were detected.

There is no horizon that may be used for conclusive correlation with the Mesa 6-1 drillhole.

OBJECTIVES AND SUMMARY OF RESULTS

Two geothermal test wells, Mesa 6-1 and Mesa 6-2, were drilled by the U.S. Bureau of Reclamation on the East Mesa anomaly in 1972 and 1973 (fig. 1). A petrographic study of the cuttings was undertaken with two main objectives in mind; first, to provide data about:

(a) the identity of the mineral phases,

(b) the chemical composition of the mineral phases, and

(c) any systematic changes in mineralogy, correlated with depth or with structural or lithologic features.

These data, plus temperature and pressure measurements in the drillholes, would allow calculations to be made about chemical reactions that would be expected to occur if geothermal waters were reinjected into the drillholes.

A second objective was to obtain information about the lithology of the section penetrated by the drillholes, specifically:

(d) to determine whether variations in lithology as reflected in cuttings samples can be correlated with porosity or other

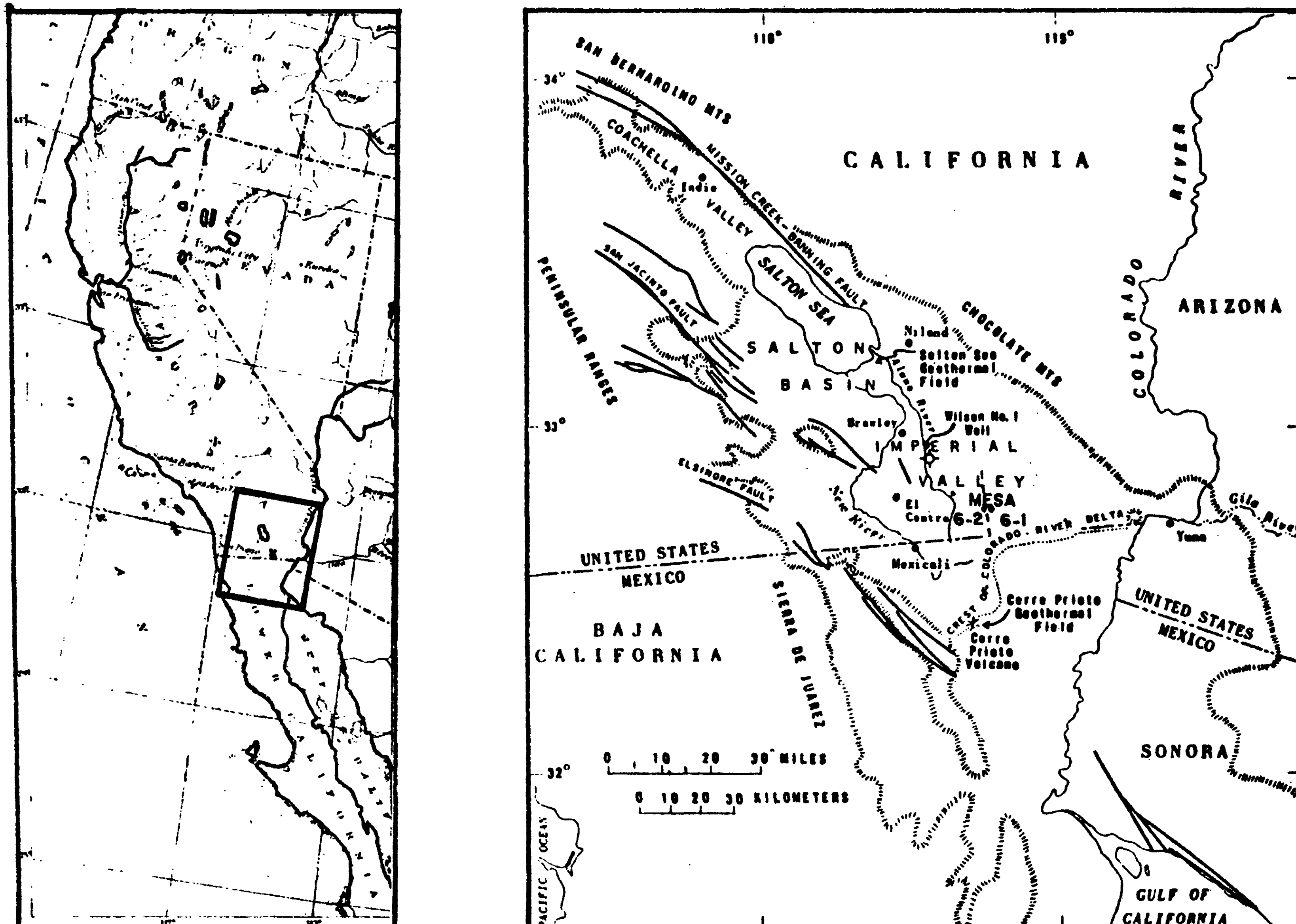

Figure 1.--Index map and generalized map of the Salton trough showing location of the Mesa 6-1 and 6-2 drillholes. Index base map, U.S.G.S. (1956). Generalized map modified from Muffler and White (1969). The dashed north-south line between Mesa 6-1 and 6-2 on the generalized map is the inferred Holtville fault.

physical properties as interpreted from geophysical logs, and to provide data permitting correlation with the results of other studies, such as stable isotopes;

(e) to determine the variations of lithology with depth, and to identify any lithologic zones which might be correlated with similar zones in Mesa 6-1 or other drillholes;

(f) to determine, if possible, whether the geophysically inferred Holtville fault, the trace of which runs north-south between the two drillholes, produced any vertical displacement.

In summary, the results of this study are:

(a) The mineral phases found in the cuttings are quartz, K-feldspar, plagioclase, calcite, dolomite, illite, chlorite, fully expandable montmorillonite, mixed layer clays, kaolinite, and pyrite. No zeolites were detected.

(b) Plagioclase is albite (sodium-rich). Most chlorite appears to be iron-rich.

(c) Variations in mineralogy are summarized in table 2. Montmorillonite is the only mineral phase which can be correlated with depth. Dolomite occurrence is related to lithology.

(d) There is no correlation between variations in lithology as deduced from the cuttings and variations in porosity as interpreted from the geophysical logs.

(e) Variations of lithology with depth are illustrated in figure 2. Most samples include a mixture of rock types, from which it is inferred that many parts of the Mesa 6-2 drillhole penetrated thinly bedded siltstones and sandstones. Three samples of core from the Mesa 6-1 drillhole confirm the presence of thinly bedded sediments in that drillhole, but no core from the Mesa 6-2 drillhole was available for this study. Because samples of cuttings were collected every 10 feet from Mesa 6-2, as compared with every 30 feet from Mesa 6-1, the Mesa 6-2 study provides greater detail about the distribution of lithologic types (fig. 2).

A zone which contains about 10 percent pebbles, at 1,830-1,850 feet, is the only horizon which might correlate with other drillholes, but the correlation of this horizon with the pebble zone at 990-1,020 feet in the Mesa 6-1 drillhole is not considered likely. Figure 3 compares Mesa 6-2 with Mesa 6-1.

(f) The evidence is insufficient to reach a conclusion about the existence or displacement of the inferred Holtville fault.

METHODS

The cuttings furnished for this study had been taken at intervals of 10 feet. Specified intervals are the reported well depths at the time of sampling, in feet below land surface. The Mesa 6-2 drillhole is located only 1,500 feet west of the Mesa 6-1 drillhole; land surface is 14 feet lower at Mesa 6-2 (U.S. Bureau of Reclamation, 1973a). The lithologic types present in each 10-foot interval were identified using a reflecting microscope (30X magnification).

Standard petrographic and X-ray diffraction methods of mineral identification were used. Each interval from 2,400 feet down was carefully examined visually, and the percentages of the various rock types were estimated. Above 2,400 feet, optical examination was of value chiefly in searching for pebbles, but even these become embedded in mud and can be detected only after washing combined with manual disintegration. At these levels, X-ray studies were conducted chiefly to determine the presence or absence of montmorillonite and kaolinite. Ten samples of hand-separated and hand-washed siltstone fragments (at 1,400 feet and every 100 feet from 1,800 to 2,400 feet) were X-rayed before and after glycolation and heat treatment, to determine whether montmorillonite was present in siltstone presumably uncontaminated with drilling mud. Four clay fractions, less than 2μm (micrometres) two from above 2,400 feet (1,000 and 2,000 feet) and two from deeper levels (2,950 and 4,700 feet), were separated and studied by glycolation, heat treatment, and the DMSO technique, to detect the presence of kaolinite. The drilling mud was also studied in this way. The DMSO technique was used because it was not possible, in this suite of cuttings, to rely on the detection of double X-ray diffraction maxima representing both kaolinite and chlorite in the range 12.2°-12.4°2θ (7.25-7.15Å) or in the range 24.5°-25°2θ (3.6-3.5Å). Even the use of slow scanning speeds failed to resolve the double maxima.

The DMSO technique, described by Garcia and Camazano (1968), consists of refluxing the clay material in DMSO (dimethyl-sulphoxide) on a water bath for 8 hours. In our procedure, the less than 2μm clay fraction was first acid-treated for about 12 hours in 6N HCl at 60°C to remove the chlorite, then washed. About 10 milligrams of DMSO (concentrated) were used for 50 milligrams of clay. After DMSO treatment, the material was allowed to evaporate to dryness on a glass slide under a heat lamp, and was then X-rayed. If kaolinite is present, the 7.15Å (12.4°2θ) peak shifts to 11.2Å (7.9°2θ) after saturation with DMSO.

At selected intervals throughout the drillhole, individual rock types and minerals were separated from the cuttings for detailed study. In particular, individual feldspar grains were separated for determination of refractive indices in immersion oils using a petrographic microscope; chlorite grains from some rock types were observed in oils; and black grains were separated to test for the presence of sulfur.

To facilitate comparison of the rock types found in this drillhole with other rocks in the region, the colors of the siltstones and sandstones were calibrated against the standard Rock-Color Chart which is distributed by the Geological Society of America (1963). These color names and symbols appear in square brackets after each lithologic name in this report, and in table 1. Samples of siltstones from Mesa 6-1 cuttings have also been calibrated and appear in table 1 for comparison with Mesa 6-2 cuttings.

Additives were not as great a problem in studying the cuttings of the Mesa 6-2 drillhole as they were for the Mesa 6-1 drillhole because (a) very little coarse mica was introduced in drilling, (b) other additives such as cellulose, plastic, and metal were easily recognized, and (c) samples of drilling mud and cement were available for laboratory study. The drilling mud still presented special problems, since it is

Table 1.--Colors of siltstones and sandstones in cuttings from the Mesa 6-1 and Mesa 6-2 drillholes

[By comparison with Rock-Color Chart distributed by Geological Society of America, 1963]

Rock type	Color in Mesa 6-1	Color in Mesa 6-2
Light gray and medium gray siltstone--------------------	N5, Medium gray	N5, Medium gray
	N6, Medium light gray	N6, Medium light gray
	N7, Light gray	
Dark gray siltstone-------------	N4, Medium dark gray	N4, Medium dark gray
	N3, Dark gray	N3, Dark gray
Red siltstone-------------------	5YR 4/1, Brownish gray	5R 4/2, Grayish red
	5R 6/2, Pale red	5R 6/2, Pale red
	5YR 5/2, Pale brown	5R 2/2, Blackish red
	5R 4/2, Grayish red	10R 4/2, Grayish red
Buff siltstone------------------	Not present	10YR 6/2, Pale yellowish brown

Table 1.--Colors of siltstones and sandstones in cuttings from the Mesa 6-1 and Mesa 6-2 drillholes--Continued

Rock type	Color in Mesa 6-1	Color in Mesa 6-2
Pink siltstone------------------	5YR 6/1, Light brownish gray 5YR 5/2, Pale brown 5R 6/2 and 10R 6/2, Pale reds	Not present
Silty, very fine-grained light gray sandstone----------------	Not calibrated	N7, Light gray
Silty, very fine-grained buff sandstone---------------------	Not present	10YR 6/2, Pale yellowish brown
Very fine to fine-grained white sandstone---------------	Not calibrated	N9, White
Very fine to fine-grained buff sandstone----------------	Not present	10YR 6/2, Pale yellowish brown
Fine to medium-grained white sandstone---------------	Not calibrated	N9, White

composed chiefly of montmorillonite, with considerable illite and chlorite and small amounts of quartz and calcite. All these mineral phases also occur in the siltstones and sandstones. The drilling mud does not, however, contain detectable kaolinite or mixed layer clays.

ACKNOWLEDGMENTS

The material studied was supplied by the U.S. Bureau of Reclamation, who also in part supported this study.

I am also indebted to Randy L. Bassett, graduate student at Stanford University and part-time employee of the U.S. Geological Survey, for acquainting me with the DMSO technique and for setting up the apparatus required and carrying out the DMSO saturations on five samples.

MINERALOGY

Eleven mineral phases were identified in the cuttings of the Mesa 6-2 drillhole: quartz, K-feldspar (microcline), plagioclase (albite), calcite, dolomite, pyrite, illite, chlorite (probably iron-rich), fully expandable montmorillonite, mixed layer clays (apparently random mixed layer), and kaolinite. No zeolites were found. Epidote was not identified optically and is not present in sufficient amount to show up in whole-rock X-ray diffractograms except at 4,790-4,800 feet, where the identification is tentative. In contrast to the Mesa 6-1 drillhole, ankerite is absent, and no sulfur was detected. Graphite was also looked for but not detected.

In the sediments penetrated by both the Mesa 6-2 drillhole and the

Mesa 6-1 drillhole, the mineralogy is consistent with derivation from Colorado River sediments rather than from the surrounding high mountain ranges (Merriam and Bandy, 1965; Muffler and Doe, 1968). Biotite, hornblende, and augite, principal heavy minerals in the local Peninsular Ranges, were not found in the cuttings from these two Mesa drillholes. Calcite is abundant and dolomite is commonly present; plagioclase is much less abundant than K-feldspar, and it is of albite composition. Table 2 summarizes the mineralogy of samples of cuttings which were studied by X-ray diffraction.

Quartz and calcite occur in each of the 89 whole-rock samples that were analyzed by X-ray diffraction. Quartz is a major constituent in all samples. Calcite is a major constituent in 78 samples, moderate in eight, and a minor constituent in the other three. (See p. 26 for definition of abundance of a mineral.) Calcite occurs both as fine-grained cementing material in the sandstones and siltstones, and as fibrous vein material; in some fragments of calcite vein material, two rows of calcite fibers, aligned perpendicular to the vein margin, are discernible. Loose rhombs of calcite, common in the Mesa 6-1 drillhole below 5,300 feet, occur in only a few samples in the Mesa 6-2 drillhole.

K-feldspar (microcline) and plagioclase (albite) are present in at least 83, and possibly as many as 87 samples of the 89 studied. Each feldspar is missing from different intervals. With the exception of the interval 4,800-4,810 feet, none of the samples X-rayed were completely lacking in feldspar. K-feldspar is generally present in major to minor amounts (major in 30, moderate in 12, minor in 37 samples); it was present in trace amounts in only three (possibly seven) of the 83 (possibly 87) samples in which it occurred. When grains of feldspar are hand-separated for study in immersion oils, nearly all the coarse-grained feldspar is found to be microcline (K-feldspar); plagioclase is comparatively rare in this size range. Plagioclase is also less abundant than microcline in the whole-rock samples, even taking into account the fact that equal percentages by weight of Amelia albite and of adularia (K-feldspar) produce a higher 28°2θ peak for albite than the equivalent 27.6°2θ peak for adularia. (This was determined during the calibration runs for determining mineral percentages in the Mesa 6-1 drillhole). Of 83 (possibly 87) samples containing detectable plagioclase, plagioclase is a major constituent in 12 samples, moderate in 14, minor in 53, and present in trace amounts in five to eight samples. The X-ray diffraction pattern for this plagioclase is consistent with an albite composition (more than 90 percent sodium end-member), and this is confirmed by refractive index data obtained on some hand-separated fragments. The plagioclase, seen through the petrographic microscope with crossed nicols, is unzoned. Although it is possible that the very fine-grained plagioclase which could not be studied optically is of a different composition, the uniformity of the X-ray diffraction patterns of plagioclase in whole rocks and hand-separated plagioclase (strongest peak is at 28°2θ, 3.19Å) (Borg and Smith, 1968) makes it highly probable that most of the plagioclase is in the albite range.

Dolomite occurs in 60 of the 89 samples, and may be present in very small amounts in six other samples. It is generally present in trace amounts, but above 2,350 feet it is a minor to major constituent (eight samples), and it also occurs as a minor component in six other samples, the deepest at 5,400-5,410 feet. The deepest positive identification of dolomite was at 5,960-5,970 feet. Dolomite is absent from most samples which are dominantly composed of loose sand.

Pyrite was found by X-ray diffraction methods in at least 60 of the 89 samples, and may be present in as many as 11 others. It occurs only in trace amounts except in the intervals 4,060-4,070 feet and 5,300-5,310 feet, where it is a minor constituent.

Clay minerals

Samples of the drilling mud used in Mesa 6-2 were studied in order to determine what effect drilling mud in the pores of cuttings chips might have on the X-ray diffraction patterns of whole-rock cuttings samples. The drilling mud is composed predominantly of a fully expandable montmorillonite, with moderate amounts of illite and chlorite and minor amounts of quartz and calcite. No kaolinite or mixed layer clay was detected.

Four problems were encountered in dealing with the clay mineralogy of the cuttings.

1. Separation of the effects of the drilling mud from the characteristics of the minerals originally present in the rock material.
2. Detection of kaolinite in the presence of chlorite, and sometimes of montmorillonite as well.
3. Characterization of the chloritic phase or phases.
4. Distribution and characterization of mixed layer clays.

Montmorillonite

Fully expandable montmorillonite was identified in diffractograms of glycolated whole-rock samples down to 3,000 feet and in clay fractions (<2μm) at 4,700 and 5,000 feet. However, interpretation of whole-rock patterns is ambiguous; it is never certain whether the rock is contaminated with the drilling mud. For example, at 4,700 feet the clay fraction of the whole rock contains abundant montmorillonite, and hand-separated samples of the buff very fine to fine-grained sandstone and of the buff siltstone contain traces of montmorillonite, but the other three types of siltstone from 4,700 feet contain no montmorillonite. At 5,280 feet, eight rock types were hand-separated and washed (the four types of siltstone, buff silty to very fine-grained sandstone, the two very fine to fine-grained sandstones, and the white fine to medium-grained sandstone), and of these, only the buff siltstone contained montmorillonite. Indeed, except for an interval between 2,000 feet and 2,500 feet, the buff siltstone contains montmorillonite (fully expandable) in all parts of the drillhole from 1,400 feet down to 5,970 feet (the deepest sampled).

The explanation for this distribution of montmorillonite is not certain. Except in the buff siltstone (and one sample of buff very fine to fine-grained sandstone at 4,700 feet), montmorillonite does not occur in hand-separated, hand-washed samples of individual rock types below 2,200 to 2,300 feet. Because the drilling mud is predominantly fully expandable montmorillonite, and because the buff siltstone is less well cemented and presumably more porous than the other siltstones, it is possible that the drilling mud was selectively taken into the pores in the buff siltstone. This process would be aided by increased pressure with depth. It is also possible, however, that the source of the buff siltstone is different from that of the other siltstones. Without core, it is not possible to resolve the problem.

Chlorite

Chlorite occurs in every whole-rock sample studied from below 2,100 feet. It is generally a minor constituent, but major amounts are present in a few samples. Between 1,400 and 2,100 feet it occurs in small amounts in some samples. Heat treatments and acid treatments of cuttings samples from 1,000 feet indicate that chlorite is present only in trace amounts, if at all, at that depth.

As Grim (1968, p. 147) so well expressed it: "The identification of the various forms of chlorite is very difficult and may be impossible unless chemical and optical data are available to supplement the X-ray analysis. The small size of the clay-mineral particles and their less regular crystallinity cause some diffuseness of reflections and the absence of some ordinary weak reflections. As a consequence, usually it is now possible to identify a clay mineral only as belonging to the chlorite group of clay minerals." Nevertheless, it is apparent both from microscopic observations and from X-ray diffraction studies of samples before and after heat treatment that there is considerable variation in the chlorite present in the cuttings from the Mesa 6-2 drillhole. Furthermore, there is some correlation between the variety of chlorite and the specific rock type in which it occurs (fig. 4). It would be interesting to carry out a study of the chlorites in these rocks to determine the polytype, or polymorphic form, of each variety of chlorite (Bailey and Brown, 1962; Hayes, 1970). However, the small size of the chlorite particles in the siltstones would make mineral separation difficult, and the small percentages of chlorite present in the cuttings would make this a time-consuming undertaking which is beyond the scope of this report.

X-ray diffraction patterns of magnesium-rich chlorites show both a strong 7Å and a strong 14Å peak (fig. 4D); more iron-rich chlorites tend to have a low, diffuse 14Å peak or may even lack the 14Å peak (Grim, 1968, p. 147). The identity of some chlorites may be confirmed by heat treatment at 550-600°C; the 7Å peak is destroyed or greatly diminished and the 14Å peak is maintained or increased in height. For magnesium-rich chlorites, the 14Å peak increases greatly (Grim, 1968, p. 151-152). The situation is ambiguous for those chlorites that initially lack 14Å peaks (septechlorites). Heat treatment at 550-600°C may or may not bring out an identifiable 14Å peak (Carroll, 1970, tables 9 and 10). Montmorillonite also exhibits a 15Å peak, very close to the 14Å peak, but it shifts to 17Å after glycolation, whereas the 14Å peak of chlorite does not.

In the cuttings of both Mesa 6-1 and Mesa 6-2, chlorite in the siltstones has a low, often broad and indistinct, 14Å diffraction maximum, and therefore is presumably iron-rich (Grim, 1968, p. 147). It seems unlikely that small grain size is a factor in causing the poorly defined 14Å peak, because the platy chlorite in the buff sandstone is comparatively coarse grained, yet the 14Å peak of this platy chlorite is as poorly defined as the 14Å peaks of the fine-grained chlorite in the siltstones (figs. 4A and 4C).

Chlorite in the siltstones is too fine-grained for optical study, but its identification is confirmed in cuttings from depths below 2,100 feet by glycolation and heat treatment of hand-separated siltstone fragments. The results vary somewhat according to the type of siltstone and depth in the drillhole. In the buff siltstones from depths above 2,500 feet, chlorite may be absent, as no peak appeared at 14Å after heating at 550°C for 1 hour. Below 2,500 feet, 14Å peaks did appear after 550°C heat treatment, confirming the presence of chlorite in addition to the large amounts of montmorillonite present. The light gray siltstones were sampled between 2,100 and 5,970 feet. After heating at 550°C, they consistently developed a peak at approximately 14Å, generally displaced 0.1° to 0.3°2θ (0.2-0.7Å) toward higher 2θ values (lower d-spacings)(fig. 4A). The chlorite in the red siltstones gives similar results but has smaller and broader 14Å peaks than the chlorite in the light gray siltstones, after similar heat treatment. Only two samples of dark gray siltstone, from 5,280-5,290 feet and 5,970-5,980 feet, were heat treated. Results differed, the shallower sample showing the more pronounced increase in the height of the 14Å peak, and a greater shift toward higher 2θ values.

The shift of the 14Å peak at about 550°C is due to a decrease in the c_o cell dimension, presumably associated with loss of water from the brucite layer in the chlorite structure (Grim, 1968, p. 342; Brindley and Ali, 1950, p. 25-26 and p. 30). Because the heat treatments carried out in this study were simply done in a preheated, on-off furnace for a period of 1 hour, with no control of heating rate as in dehydration studies or differential thermal analysis (DTA) studies, the amount of peak shift cannot be compared to that in other studies (Brindley and Ali, 1950; Shirozu, 1962). Moreover, composition of the chlorite affects its thermal behavior; although 550°C is below the range of temperatures over which dehydration of the brucite layer in well-crystallized magnesium-rich chlorites occurs (Brindley and Ali, 1950, p. 29-30), the same temperature is well within the range of temperatures for breakdown of well-crystallized, more iron-rich chlorites (Shirozu, 1962, p. 24). In addition to the effect of composition on peak shift, the effect of grain size is unknown, but Grim (1968, p. 341) predicts that clay-mineral sized chlorites might show thermal reactions at somewhat lower temperatures than well-crystallized, coarser grained chlorites of equivalent composition.

Some chlorite in the silty, very fine-grained light gray sandstone is coarse-grained enough for study with a petrographic microscope. Most grains are a dark brown chlorite, with very low birefringence, and are not pleochroic. A few are green, also with low birefringence and without pleochroism. Many chlorite grains appear to be intergrowths of smaller chlorite crystals. The optical properties are consistent with those of type-I chlorites as described by Hayes (1970, p. 289), the reddish brown color presumably indicating some oxidation of iron.

In the study of the Mesa 6-1 drillhole (Fournier, 1973, p. 10), this rock type was described as "silty, very fine-grained light gray sandstone, containing biotite." The biotite identification was based on the black appearance of the platy mineral, as seen with the reflecting microscope, and on a whole-rock X-ray diffraction peak at 10Å. Further study at the present time shows that the "biotite" is in reality the same dark brown chlorite that occurs in the rock in the Mesa 6-2 drillhole. The 10Å whole-rock X-ray peak results from the presence of illite.

X-ray and heating studies of four samples of the "silty, very fine-grained sandstone with dark brown chlorite" in Mesa 6-2 (at 4,290, 5,030, 5,140, and 5,190 feet) show that in each case there is a marked (50-300 percent) increase in the height of the 14Å peak when heated at 550°C for 1 hour, with little or no 2θ shift (<0.2°2θ; <0.5Å)(fig. 4B). Without detailed X-ray and optical work on separated chlorites (Hayes, 1970), it is not clear whether this chlorite is the same polytype as that in the light gray siltstones and the red siltstones.

A platy green variety of chlorite occurs in the buff very fine to fine-grained sandstone. This chlorite is non-pleochroic, of low birefringence, with refractive index markedly greater than 1.57. One of two samples X-rayed (from 5,290 feet) showed a strong (>50 percent) increase in the height of the 14Å peak after heating at 550°C, but no shift (fig. 4C). The second sample (from 5,340 feet) showed only a slight increase in peak height, accompanied by broadening of the 14Å peak.

The chlorite found in the metamorphic rock fragments is clearly different from the chlorites described above (fig. 4). It has a sharp prominent 14Å peak before heat treatment, and the 7Å:14Å peak height ratio ranges from greater than 3:1 to 5:1. Therefore, the chlorite is probably magnesium-rich (Grim, 1968, p. 147). Four samples (from 3,200, 4,540, 4,700, and 5,340 feet) were studied by heat treatment. At 350°C, the height of the 14Å peak decreased very slightly or not at all. After heating at 550°C, three samples showed a very large increase in the height of the 14Å peak, to two or three times that before heating (fig. 4D) but the 14Å peak in one sample (from 4,540 feet) increased only 10 percent. All samples showed a shift of the 14Å peak, to higher 2θ values, of 0.2° to 0.4°2θ (0.5-0.9Å). These chlorite samples are of minimal significance in terms of their quantity in the cuttings. They were studied as a basis for comparison, and it is evident that whatever the origin of the chlorite in the siltstones and sandstones, it is a different mode of origin from that of the chlorite-quartz-albite-muscovite pebbles derived from nearby chlorite schists. Presuming that the chlorite in the metamorphic rock fragments has the IIb chlorite structure, as has been found by other investigators to be typical of detrital chlorite (Bailey and Brown, 1962; Hayes, 1970), some of the other varieties of chlorite in these sedimentary rock cuttings may have one of the type-I structures characteristic of authigenic chlorite. It would be of interest to know the polytypes of the chlorite varieties, but chlorite is present in such small percentages in these samples, that there is little possibility of determining polytypes.

Illite

Illite is found in hand-separated samples of each of the four types of siltstones, and in smaller amounts in the sandstones. In whole-rock samples its abundance varies from a minor to a major constituent, but it is present in moderate (49 samples) or minor (36 samples) amounts in all but a few samples. Because the drilling mud contains significant amounts of illite, there is a good possibility of contamination in all whole-rock samples. Nevertheless, the larger amounts of illite are found in cuttings samples which contain smaller proportions of sand and sandstone and larger proportions of siltstone.

Mixed layer clays

Mixed layer clays, which cannot be attributed to drilling mud, appear to be present throughout the section. Most whole-rock diffractograms contain many small extra peaks in the region from 6.3° to 8.9°2θ (14 to 10Å), and also some in the ~3° to 6.3°2θ (29.4 to 14Å) region; however, no consistent pattern emerges. The mixed layering is probably a random interlayering of illite and montmorillonite. At 4,700 feet, each of the four siltstones was hand-separated and glycolated. Only the buff siltstone contains montmorillonite (plus illite and chlorite); but X-ray diffractograms of all four siltstones have extra peaks between 6.3° and 8.9°2θ, which show especially well after glycolation.

Kaolinite

In addition to the drilling mud, clay fractions from four whole-rock samples were tested for the presence of kaolinite by the DMSO procedure. These samples were from 1,000-1,010 feet, 2,000-2,010 feet, 2,950-2,960 feet, and 4,700-4,710 feet. The drilling mud contained a faint trace of kaolinite. The four cuttings samples, however, have at least 5 percent kaolinite in the clay fraction.

Pyrite

Pyrite was identified by X-ray diffraction methods in at least 60, and possibly 71, of the 89 X-rayed samples. In the Mesa 6-2 drillhole, pyrite commonly appears in X-ray diffraction patterns of samples in which it could not be observed visually with the reflecting microscope (30X). It was optically visible in only 22 of the 89 samples which were studied by X-ray, and only in samples from below 3,500 feet. However, in 10 of these 22 samples pyrite did not show up in the whole-rock X-ray diffraction pattern. Samples containing coarse grained pyrite seem especially likely not to give detectable X-ray diffraction maxima characteristic of pyrite. In the cuttings of the Mesa 6-1 drill-hole, pyrite could be easily identified with the reflecting microscope in many samples, and yet appeared in only seven whole-rock X-ray diffractograms. It seems probable that much of the pyrite in the cuttings from the Mesa 6-2 drillhole is very fine-grained.

VARIATIONS IN MINERAL CONTENT

In the study of the cuttings from the Mesa 6-1 drillhole, quantitative estimates of the percentages of quartz, feldspars, calcite, and dolomite were made by comparing X-ray diffractograms of whole-rock samples with diffractograms of various weighed mixtures of standard minerals. The results showed that there was no simple variation in proportions of mineral phases with depth (Fournier, 1973, p. 29-31). It became apparent early in the study of the cuttings from the Mesa 6-2 drillhole that it would not be a wise use of time to pursue similar calculations for this drillhole. Therefore amounts of mineral phases were estimated from the whole-rock diffraction patterns, run at range 100, time constant 3, scale expansion 2, scanning speed 2° per minute, chart speed 1 inch/min, and using the most prominent peak for each phase and the following conventions:

Major: peak height greater than 40 divisions (out of 100 total) above background

Moderate: peak height between 25 and 40 divisions above background

Minor: peak height 10 to 25 divisions above background

Trace: highest peak height less than 10 divisions

These abundances are summarized in table 2. Although the method is qualitative, and does not take into account the fact that a quartz 3.34Å peak that is 30 divisions high does not mean the same as an albite 3.19Å peak that is 30 divisions high, it does provide a useful indicator of variations in proportion of a single mineral phase from one interval to another, and is as accurate as is justified by the reliability of the sampling.

As may be seen from table 2, five mineral phases are present throughout the drillhole, with minor exceptions. These are quartz, K-feldspar, plagioclase (albite), calcite, and illite. Chlorite certainly is present below 2,100 feet, and probably extends to shallower depths. Mixed layer clays are also present in almost all cuttings samples, but amounts are not shown in table 2 because of the variability of the patterns and the impossibility of estimating amounts. Kaolinite is not presented in table 2 either because the time-consuming tests for its presence were only carried out at four intervals. (See p. 9-10.) It is present at least down to 4,700 feet.

Two other minerals, dolomite and pyrite, are not present in every interval that was studied by X-ray methods. The distribution of pyrite

Table 2.--Variations in mineral content in whole-rock samples (as determined by X-ray diffraction)

[n.d. = no data]

Depth interval (feet)	Quartz	K-Feldspar	Albite	Calcite	Dolomite	Illite	Chlorite	Montmorillonite
360-370---------	Major	Major	Major	Major	Minor	Minor	Trace ?	n.d.
420-430---------	Major	Major	Major	Major	Minor	Trace	Trace ?	Minor
1,000-1,010-------	Major	Minor	Moderate	Major	Moderate	Moderate	Trace	Minor
1,480-1,490-------	Major	Major	Major	Major	Major	Moderate	Trace	Minor
1,990-2,000-------	Major	Moderate	Moderate	Major	Minor	Minor	Minor	Minor
2,000-2,010-------	Major	Moderate	Moderate	Major	Moderate	Moderate	Minor	None
2,100-2,110-------	Major	Minor	Minor	Major	Minor	Minor	Minor	Trace
2,200-2,210-------	Major	Minor	Moderate	Major	Minor	Minor	Minor	Trace
2,310-2,320-------	Major	Major	Major	Major	Minor	Minor	Minor	Trace
2,400-2,410-------	Major	Major	Minor	Major	Trace	Minor	Minor	None
2,500-2,510-------	Major	Minor	Minor	Major	Trace	Moderate	Minor	None
2,600-2,610-------	Major	Minor	Minor	Major	Trace	Minor	Minor	None
2,700-2,710-------	Major	Minor	Minor	Major	Trace	Minor	Minor	Trace
2,800-2,810-------	Major	Minor	Trace	Major	Minor	Major	Major	n.d.
2,900-2,910-------	Major	Minor	Minor	Major	Trace	Moderate	Minor	n.d.
2,950-2,960-------	Major	Major	Minor	Major	Trace	Minor	Minor	Trace
3,000-3,010-------	Major	Trace	Minor	Major	Trace	Minor	Minor	Trace
3,050-3,060-------	Major	Minor	Minor	Major	Trace	Minor	Minor	n.d.
3,100-3,110-------	Major	Minor	Minor	Major	Trace	Moderate	Minor	n.d.
3,150-3,160-------	Major	Moderate	Minor	Major	Minor	Minor	Minor	n.d.
3,200-3,210-------	Major	Moderate	Trace	Major	Minor	Moderate	Minor	n.d.
3,240-3,250-------	Major	Trace	Minor	Major	Minor	Moderate	Minor	n.d.

Table 2.--Variations in mineral content in whole-rock samples (as determined by X-ray diffraction)--Continued

Depth Interval (feet)	Quartz	K-Feldspar	Albite	Calcite	Dolomite	Illite	Chlorite	Montmorillonite
3,300-3,310-------	Major	Minor	Moderate	Major	Trace	Moderate	Minor	None
3,350-3,360-------	Major	Minor	Minor	Major	Minor	Moderate	Minor	n.d.
3,400-3,410-------	Major	Minor	Minor	Major	Trace	Moderate	Moderate	n.d.
3,450-3,460-------	Major	Minor	Minor	Major	Trace	Moderate	Moderate	n.d.
3,500-3,510-------	Major	Major	Major	Major	Trace	Minor	Minor	n.d.
3,550-3,560-------	Major	Major	Major	Major	None	Minor	Minor	n.d.
3,600-3,610-------	Major	Major	Minor	Major	Trace	Moderate	Minor	n.d.
3,650-3,660-------	Major	Minor	Minor	Major	Trace	Moderate	Minor	n.d.
3,700-3,710-------	Major	Trace (?)	Minor	Major	Trace	Minor	Minor	n.d.
3,760-3,770-------	Major	Minor	Minor	Major	None	Moderate	Minor	n.d.
3,800-3,810-------	Major	Minor	Minor	Major	Trace	Moderate	Minor	n.d.
3,850-3,860-------	Major	Major	Minor	Major	Trace	Minor	Minor	n.d.
3,900-3,910-------	Major	Moderate	Minor	Major	None	Minor	Minor	n.d.
3,930-3,940-------	Major	Moderate	Minor	Major	?	Moderate	Minor	n.d.
3,990-4,000-------	Major	Minor	Minor	Minor	None	Minor	Minor	n.d.
4,060-4,070-------	Major	Major	Major	Major	?	Moderate	Minor	n.d.
4,100-4,110-------	Major	Minor	Minor	Major	Trace	Moderate	Minor	n.d.
4,150-4,160-------	Major	Minor	Minor	Major	?	Moderate	Minor	n.d.
4,200-4,210-------	Major	Minor	Minor	Major	Trace	Moderate	Minor	n.d.
4,250-4,260-------	Major	Major	Minor	Moderate	None	Minor	Trace	n.d.
4,300-4,310-------	Major	Moderate	Major	Moderate	?	Moderate	Minor	n.d.
4,350-4,360-------	Major	Moderate	Minor	Major	?	Moderate	Minor	n.d.
4,400-4,410-------	Major	Major	Moderate	Major	None	Minor	Minor	n.d.
4,450-4,460-------	Major	Major	Moderate	Major	None	Minor	Minor	n.d.

Table 2.--Variations in mineral content in whole-rock samples (as determined by X-ray diffraction)--Continued

Depth interval (feet)	Quartz	K-Feldspar	Albite	Calcite	Dolomite	Illite	Chlorite	Montmorillonite
4,510-4,520-------	Major	Major	Minor	Major	None	Minor	Minor	n.d.
4,550-4,560-------	Major	Major	None	Major	None	Moderate	Minor	n.d.
4,600-4,610-------	Major	Major	Moderate	Major	Trace	Moderate	Minor	n.d.
4,700-4,710-------	Major	Major	Moderate	Major	Trace	Minor	Minor	Trace
4,710-4,720-------	Major	Major	Major	Moderate	Trace	Minor	Minor	n.d.
4,720-4,730-------	Major	Minor	Moderate	Major	Trace	Moderate	Minor	n.d.
4,730-4,740-------	Major	Moderate	Minor	Major	None	Moderate	Minor	n.d.
4,740-4,750-------	Major	Minor	Minor	Major	Minor	Moderate	Minor	n.d.
4,750-4,760-------	Major	Minor	Minor	Major	Trace	Moderate	Minor	n.d.
4,760-4,770-------	Major	Minor	Minor	Major	Trace	Moderate	Minor	n.d.
4,770-4,780-------	Major	Minor	Trace	Major	Trace	Moderate	Minor	n.d.
4,780-4,790-------	Major	Major	Minor	Major	Trace	Moderate	Minor	n.d.
4,790-4,800-------	Major	Minor	Minor	Major	Trace	Moderate	Minor	n.d.
4,800-4,810-------	Major	Trace	?	Major	None	Major	Moderate	n.d.
4,880-4,890-------	Major	Major	Trace	Minor	Trace	Minor	Minor	n.d.
4,920-4,930-------	Major	Major	Moderate	Major	Trace	Moderate	Minor	n.d.
5,000-5,010-------	Major	Moderate	Minor	Moderate	None	Minor	Trace	n.d.
5,100-5,110-------	Major	Major	Major	Major	Trace	Minor	Minor	n.d.
5,190-5,200-------	Major	Major	Major	Major	None	Moderate	Moderate	n.d.
5,250-5,260-------	Major	Major	Moderate	Major	None	Moderate	Minor	n.d.
5,260-5,270-------	Major	Minor	Minor	Moderate	?	Minor	Minor	n.d.
5,270-5,280-------	Major	Major	Minor	Major	None	Minor	Minor	n.d.
5,280-5,290-------	Major	Trace	Minor	Major	Trace	Moderate	Moderate	n.d.
5,290-5,300-------	Major	Minor	Minor	Major	None	Moderate	Minor	n.d.

Table 2.--Variations in mineral content in whole-rock samples (as determined by X-ray diffraction)--Continued

Depth interval (feet)	Quartz	K-Feldspar	Albite	Calcite	Dolomite	Illite	Chlorite	Montmorillonite
5,300-5,310-------	Major	None	Moderate	Major	Trace	Moderate	Moderate	n.d.
5,310-5,320-------	Major	Minor	Minor	Major	Minor	Moderate	Minor	n.d.
5,320-5,330-------	Major	None	Minor	Major	Trace	Moderate	Minor	n.d.
5,330-5,340-------	Major	Minor	Minor	Major	None	Moderate	Moderate	n.d.
5,340-5,350-------	Major	Major	Moderate	Major	Trace	Major	Moderate	n.d.
5,350-5,360-------	Major	Major	Minor	Moderate	None	Minor	Minor	n.d.
5,360-5,370-------	Major	Major	Moderate	Major	None	Minor	Minor	n.d.
5,370-5,380-------	Major	Moderate	Minor	Major	None	Moderate	Minor	n.d.
5,380-5,390-------	Major	Minor	Minor	Major	None	Minor	Minor	n.d.
5,400-5,410-------	Major	Major	None	Major	Minor	Moderate	Moderate	n.d.
5,450-5,460-------	Major	Minor	Minor	Major	Trace	Moderate	Minor	n.d.
5,490-5,500-------	Major	Moderate	Moderate	Major	Trace	Minor	Minor	n.d.
5,550-5,560-------	Major	Minor	Minor	Major	Trace	Moderate	Minor	n.d.
5,600-5,610-------	Major	Trace	Minor	Major	Trace	Moderate	Moderate	n.d.
5,700-5,710-------	Major	Minor	Minor	Major	Trace	Moderate	Minor	n.d.
5,800-5,810-------	Major	Minor	Major	Major	Minor	Moderate	Minor	n.d.
5,900-5,910-------	Major	Moderate	Moderate	Moderate	None	Minor	Minor	n.d.
5,960-5,970-------	Major	Trace	Minor	Major	Minor	Moderate	Minor	n.d.
5,970-5,980-------	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	Minor
5,990-6,000-------	Major	Moderate	Minor	Minor	None	Minor	Trace	n.d.

has been discussed (p. 24). The distribution of dolomite is of particular interest because, although it cannot be correlated with depth, it can be correlated with lithology. Dolomite is absent from samples which are composed predominantly of loose sand, and with few exceptions is present in other intervals where loose sand is absent or occurs in small amounts. (Compare fig. 2 with table 2.) For example, the cuttings samples from 5,900-5,910 feet and 5,990-6,000 feet are composed predominantly of loose sand, and lack dolomite, whereas at 5,960-5,970 feet the cuttings contain only 10 percent sand, and dolomite is present as a minor constituent.

Montmorillonite (fully expandable) is the only mineral phase which can be correlated with depth. As can be seen in table 2, it disappears somewhere between 2,300 and 2,500 feet in all rock types except the buff siltstone.

COMPARISON WITH SALTON SEA GEOTHERMAL FIELD

The maximum recorded temperature in the Mesa 6-2 drillhole was 187°C, at 6,005 feet (Swanberg, 1973). In the Mesa 6-1 drillhole, the temperature at 6,000 feet was 183°C, and the maximum temperature, at 8,000 feet, was just under 200°C (U.S. Bureau of Reclamation, 1973b). Although these temperatures are not necessarily the same as the original formation temperatures before drilling (Muffler and White, 1969), temperatures in the two drillholes probably differed by only a few degrees centigrade at equivalent depths.

The temperatures attained in these two Mesa geothermal wells are not high enough to induce many of the metamorphic reactions described by Muffler and White (1969) at the Salton Sea geothermal field 35 miles to the north, where bottom hole temperatures reached 325°C at 5,000 feet, and in the much deeper Wilson No. 1 well, 15 miles to the northwest, where the temperature at 13,443 feet was 260°C. No newly formed epidote was positively identified in the Mesa drillholes, and there was no systematic variation in mixed layer illite-montmorillonite. However, some comparisons can be made. The persistence of dolomite to the bottom of the Mesa 6-2 drillhole in the siltstone horizons is consistent with temperatures of disappearance of dolomite of 200°C to 260°C estimated for the Salton Sea field. In the Mesa 6-1 drillhole, dolomite occurs down to 4,900 feet, and more sporadically down to 6,620 feet, equivalent to 185°C. A single occurrence below that level, at 7,697 feet, may have sloughed downward.

Ankerite was found in only trace amounts and in only six or seven cuttings samples from Mesa 6-1, the shallowest at 3,680 feet (168°C) and the deepest at 6,500 feet (184°C). The temperature range postulated by Muffler and White (1969) ranged from 120°C (possibly as low as 80°C), to something lower than 180°C, possibly as low as 125°C. Ankerite was not present at all in cuttings from Mesa 6-2. Its absence was unexpected.

Kaolinite is present at least down to 4,700 feet (177°C) in the Mesa 6-2 drillhole; this is within the temperature range at which kaolinite was present in the I.I.D. No. 1 well (200°C), but above the temperature at which kaolinite disappeared in the Wilson No. 1 well (160°C) (Muffler and White, 1969). Kaolinite was not identified in Mesa 6-1 cuttings, but was probably present, masked by chlorite. Since the DMSO technique was not used on those cuttings, it would not have been detected.

Chlorite was first detected, in individual siltstone samples, in the Mesa 6-2 drillhole at 1,400 feet (equivalent to 115°C if the same curve used for Mesa 6-1 is assumed for Mesa 6-2 (U.S. Bureau of Reclamation, 1973b)). This is a somewhat lower temperature than postulated by Muffler and White (1969). In the Mesa 6-1 drillhole, the first appearance of chlorite is less certain but is at least as shallow as 1,690 feet, equivalent to 126°C, which is the lower temperature limit suggested by Muffler and White. In both drillholes, it is possible that some chlorite occurs at shallower levels but is masked by montmorillonite.

Montmorillonite in the Mesa 6-1 drillhole dies out between 1,450 feet and 1,690 feet (equivalent to 115°C to 126°C), a considerably higher temperature than the temperature of disappearance (100°C) cited by Muffler and White (1969). In the Mesa 6-2 drillhole, montmorillonite occurs in all the siltstones as deep as 2,200 to 2,300 feet (150°C), and the persistence of montmorillonite down to 5,970 feet, in the buff siltstone only, is puzzling.

In the Mesa 6-2 drillhole, chlorite is present with both kaolinite and dolomite in the same cuttings samples from 1,400 feet (115°C) down to at least 4,700 feet (177°C). The abundance of chlorite does not change systematically with depth. Minerals on opposite sides of the metamorphic reaction proposed by Muffler and White (1969), dolomite + ankerite + kaolinite + Fe^{+3} + H_2O + O^{-2} → chlorite + calcite + carbon dioxide, coexist over a wider temperature range in the Mesa 6-2 drillhole than in the wells of the Salton Sea field and the Wilson No. 1 well. This may be due chiefly to the lower temperature gradient in the vicinity of the Mesa anomaly. However, another factor may be the absence of ankerite from the Mesa 6-2 cuttings. Since chlorite and montmorillonite are the only iron-bearing phases consistently present in sizeable amounts (pyrite occurs only in trace amounts), whatever conditions prevent the formation of ankerite might be expected to favor the formation of chlorite at a lower temperature than would be the case if ankerite were present.

LITHOLOGY

As demonstrated in figure 2, many cuttings samples, although collected at 10-foot intervals, contain chips of both siltstones and sandstones, indicating that much of the Mesa 6-2 drillhole penetrates interbedded siltstones and sandstones comparable to the thin-bedded sediments found in core from the Mesa 6-1 drillhole. However, there are some 10-foot intervals which contain more than 90 percent sands and sandstones (especially between 4,150 and 4,700 feet). These horizons may be similar to the thick uniform beds of fairly well sorted sand described by Merriam and Bandy (1965). There are also some 50 to 100-foot intervals, between 2,800 and 3,100 feet, which contain more than 90 percent siltstone.

Siltstones

Below 2,400 feet, about two-thirds of the material brought to the surface as cuttings is siltstone (particle size 0.004-0.0625 millimetres on the Wentworth scale), with some claystone (indurated mudstone). As in the cuttings from the Mesa 6-1 drillhole, there are four different types of siltstone, classified by color. However, as may be seen in table 1, not all subdivisions correspond, nor is the vertical distribution of the four types of siltstone comparable to that of Mesa 6-1. (See discussion of colors of siltstones, p. 52-53, and fig. 2.) All four types of siltstone occur in most intervals between 2,550 and 6,000 feet. Red and buff siltstones reach their greatest abundance between 2,550 and 3,150 feet, and the dark gray siltstone is most abundant below 4,500 feet.

X-ray diffraction patterns of 33 samples, representing all four color types at depths from 1,400 to 5,970 feet, show that the siltstones are generally composed of major amounts of quartz and calcite, with varying amounts of illite, chlorite, feldspars, and in some places, fully expandable montmorillonite. Mixed layer clays are present in small amounts. Dolomite and (or) pyrite also occur.

Chips of at least three types of siltstone occur in each cuttings sample. No gradations of color or interfaces between color types were observed. The four color types are mineralogically similar with two exceptions: (1) the persistence of montmorillonite below 2,400 feet in the buff siltstone only; and (2) the consistent presence of significant amounts of pyrite in the red siltstone. It is not clear whether the color variations are the result of different states of oxidation in situ, or whether they reflect some differences in source material, as suggested by van de Camp (1973). However, the mineralogy indicates that all sediments penetrated by this drillhole are part of the Colorado River delta (Muffler and White, 1969; Muffler and Doe, 1968; Merriam and Bandy, 1965), rather than derived from surrounding mountain ranges.

Buff siltstone [10YR 6/2, Pale yellowish brown]: Generally comprises 20 percent or less of the cuttings, but increases to 70 percent of the cuttings from 2,800-2,810 feet and 2,980-3,000 feet. X-ray diffraction patterns of 11 hand-separated samples, chosen at depths from 1,400 to 5,970 feet, show that quartz and calcite are major constituents of all samples. In five samples (from 1,400, 1,900, 2,700, 3,000, and 5,970 feet), montmorillonite is also a major constituent; in two other samples (2,600 and 5,280 feet) it is present in trace amounts. Montmorillonite was not detected in the buff siltstone from 2,000 or from 2,400 feet. Two other samples (4,240 and 5,750 feet) were not glycolated to test for montmorillonite. Dolomite, which varies from a trace to moderate amounts, occurs in all but one sample (at 1,900 feet). Both plagioclase and K-feldspar are found in trace to minor amounts in each sample except one (at 5,750 feet) which lacks detectable K-feldspar. Chlorite and illite are found, generally in minor amounts, and mixed layer clays are present in trace amounts in all 11 samples. Trace amounts of pyrite were detected in about half the samples.

Red siltstone [5R 4/2, Grayish red, with variation to 5R 6/2, Pale red, and to 5R 2/2, Blackish red]: Generally comprises 30 percent or less of the cuttings in any one interval, but reaches 50 percent at 3,000-3,010 feet and 3,760-3,770 feet. Nine samples, hand-separated and individually X-rayed, came from depths ranging from 2,000 to 5,970 feet. Quartz and calcite are major constituents. Pyrite, in trace to minor quantities, is present in every sample. Chlorite and illite occur in all samples in trace to minor amounts, accompanied by mixed layer clays. Feldspar occurs in all samples, also in trace to minor quantities. Plagioclase is absent from one sample (2,400 feet) and K-feldspar from two (2,000 feet and 5,970 feet). Dolomite occurs in only four samples, as traces; these include the sample from 2,000 feet and the three samples from 5,280 feet and below. No montmorillonite was found in the six glycolated samples (between 2,400 and 5,970 feet), but a small amount of montmorillonite was found in a mixed sample which contained both red and light gray siltstones from 2,100 feet.

Light gray siltstone [N5, Medium gray, with some fragments N6, Medium light gray]: This rock type is abundant throughout the section, comprising at least 10 percent of the cuttings in most intervals which consist predominantly of siltstone, and 50 percent or more in some intervals between 3,390-3,540 feet, 4,010-4,050 feet, 5,190-5,350 feet, and 5,660-5,690 feet (fig. 2). Ten hand-separated samples, from depths between 2,200 and 5,970 feet, are composed of major quartz and calcite, minor amounts of chlorite and illite, and traces of mixed layer clays. No montmorillonite was found in any of the seven glycolated samples from 2,400 feet downward, but a very slight amount was detected in a glycolated sample from 2,200 feet, as well as in the mixed sample from 2,100 feet referred to in the preceding section. Dolomite, ranging from trace to minor amounts, occurs in only four samples, the deepest at 3,000 feet. K-feldspar is a major constituent of one sample (2,200 feet), but occurs only in trace amounts in four others and is absent from the other five. Plagioclase is found in trace to minor amounts in seven samples, and is absent from three. Pyrite was detected in only three samples.

Dark gray siltstone [N4, Medium dark gray, with some N3, Dark gray]: This rock type occurs throughout the section, but becomes more abundant below 4,500 feet, where it comprises as much as 20 percent of the cuttings in about one-quarter of the samples, and especially below 5,400 feet, where it comprises 20 percent or more of the cuttings in about half the samples (fig. 2).

Four hand-separated samples, ranging from 4,240 to 5,970 feet in depth, were studied. All contain major amounts of quartz, moderate amounts of illite and calcite, and minor chlorite and plagioclase (albite). K-feldspar is present in trace amounts in two of three samples in which it was checked, and dolomite was also present in those two samples. Traces of pyrite were detected in only one sample. Two samples were glycolated and showed no sign of montmorillonite. Mixed layer clays are present, but are less prominent than in the other three siltstone color types.

Sandstones and sands

Sandstones (chips of sandstone ranging from silty, very fine-grained sandstone to fine to medium-grained sandstone) plus loose sand grains (ranging from silt to very coarse sand size) make up about one-third by volume of the cuttings samples from below 2,400 feet. It is likely that the amount of sandstone and sand present in this part of the section penetrated by the drillhole is greater than one-third, because sand is easily lost in sampling. Because the sampling interval in the Mesa 6-2 drillhole was 10 feet, as compared with 30 feet in the Mesa 6-1 drillhole, it was possible to detect concentrations of loose sand which either were not present in Mesa 6-1 or were lost in sampling.

Loose sands are most abundant below 3,550 feet, and especially between 3,550 and 4,550 feet, where they comprise 80 to 95 percent of the cuttings in many intervals (fig. 2). Fine to medium-grained sandstone chips are most abundant (20-50 percent) in four depth intervals, 2,710-2,790 feet, 3,320-3,520 feet, 4,600-4,690 feet, and 5,480-5,560 feet. Finer grained sandstone chips have a similar distribution, but with less variation in abundance.

Most of the types of sandstone described from the cuttings of Mesa 6-1 are also present in Mesa 6-2. However, the two "pink" sandstones ("silty, very fine-grained, without biotite" and "very fine to fine-grained") were not found; the bright pink, dense quartzite apparently is also missing. A buff-colored [10YR 6/2, Pale yellowish brown], very fine to fine-grained sandstone which appears to contain both more feldspar (usually both K-feldspar and plagioclase) and more chlorite than the white very fine to fine-grained sandstone, occurs sporadically throughout the section below 2,500 feet. It is less common between 3,500 and 4,700 feet than in the intervals 2,500 to 3,500 feet and 4,700 to 5,750 feet. (It is not plotted separately in fig. 2, but is included with the white very fine to fine-grained sandstone.)

Sandstones

Silty, very fine-grained light gray sandstone containing dark brown chlorite (0.03-0.09 mm) [N7, Light gray]: Minerals which were identified in X-ray diffraction patterns of six hand-separated samples of this rock type, from depths ranging from 2,000 to 5,280 feet, are major quartz and calcite, (with major K-feldspar in one sample), minor plagioclase (albite) and chlorite (trace amounts of chlorite at 2,000 feet), and trace to minor amounts of illite and pyrite. K-feldspar occurs in five samples, generally in minor amounts (absent at 5,280 feet). Dolomite is present in moderate amounts at 2,000 feet and in trace amounts at 5,280 feet. Mixed layer clays also occur. Montmorillonite was not detected. This rock type occurs sporadically throughout the section below 2,000 feet. In no interval does it comprise more than 20 percent of the cuttings sample. See the discussion in the section on Chlorite, p. 21-22, for a comparison of this rock to the corresponding unit in the Mesa 6-1 drillhole.

Silty, very fine-grained buff sandstone (0.03-0.09 mm) [10YR 6/2, Pale yellowish brown]: Some samples, such as the one at 4,200 feet, have a pinkish cast [10R 6/2, Pale red]. This hand-separated sample, and also one from 5,280 feet, contain major quartz and calcite, minor plagioclase and K-feldspar, and trace amounts of illite, chlorite, mixed layer clay, and pyrite. No dolomite or montmorillonite was detected. The rock type occurs sporadically throughout the section between 2,800 feet and 5,800 feet, and is less abundant than the light gray silty to fine-grained sandstone. It is most abundant in the intervals 2,800-2,910 feet, 4,200-4,360 feet, 4,750-4,800 feet, and 5,250-5,410 feet. It is not plotted separately on figure 2, but is included with the silty, very fine-grained light gray sandstone containing dark brown chlorite.

Very fine to fine-grained white sandstone (0.06-0.15 mm) [N9, white]: This rock type occurs sporadically below about 2,400 feet, usually in small amounts, in less than 10 percent of the cuttings. It is especially abundant in certain intervals: 3,070-3,090 feet

(35-45 percent), 3,300-3,740 feet (up to 30 percent), and 4,600-4,640 feet (up to 35 percent). In figure 2, it is plotted with the very fine to fine-grained buff sandstone. (See next section.)

X-ray diffraction patterns of two samples of the very fine to fine-grained white sandstone show that it is comparable to the same rock type in the Mesa 6-1 drillhole. It consists of major quartz and calcite, minor to moderate amounts of K-feldspar and plagioclase (albite), and minor chlorite. Traces of illite are also present. The 14Å peak of the chlorite shifts to higher 2θ values (lower d-spacing) after heating at 550°C for 1 hour. No dolomite, montmorillonite, or pyrite was found by X-ray methods, although pyrite was observed in this rock type with the reflecting microscope in at least three other samples (at 3,500, 4,920, and 5,000 feet).

Very fine to fine-grained buff sandstone (0.06-0.15 mm), [10YR 6/2, Pale yellowish brown]: This rock type is optically distinguishable by the presence of feldspars and a dark green platy chlorite, both visible at 30X magnification. Five hand-separated samples, ranging from 4,700-5,340 feet in depth, all contain quartz as a major constituent and calcite in minor to major amounts. Both K-feldspar and plagioclase (albite) are present as minor constituents in every sample except one in which K-feldspar is a major constituent. Chlorite varies from trace to moderate amounts. Illite occurs in trace amounts in all samples. Pyrite is present in trace amounts in two or three samples, and dolomite as traces in two and as a minor constituent in one sample. Montmorillonite was found only in the sample from 4,700 feet; four of the five samples were glycolated.

This rock type is present sporadically between 2,600 and 5,810 feet, and is less abundant than the white very fine to fine-grained sandstone. It is particularly abundant between 2,800-2,960 feet, 3,310-3,340 feet, 4,700-4,790 feet, and at some intervals between 5,150 and 5,700 feet.

Fine to medium-grained white sandstone (0.15-0.32 mm) [N9, white]: Four samples of this sandstone, from depths ranging from 3,160 to 5,900 feet, were studied by X-ray diffraction. They are composed of major amounts of quartz, and varying amounts of feldspars; K-feldspar occurs in minor to major amounts, and plagioclase (albite) is found in major amounts at 5,900 feet and trace amounts in the other three samples. Calcite varies in abundance from traces in one sample to a major constituent in two samples; dolomite was not detected. Illite, chlorite, and mixed layer clays occur as traces in all four samples. Pyrite was found as a minor constituent at 5,900 feet and in trace amounts at 5,280 feet.

This rock type occurs sporadically below 2,540 feet, generally comprising less than 20 percent of the cuttings sample, but it is more abundant in certain sets of intervals: 2,710-2,790 feet, 3,160-3,170 feet, 3,320-3,520 feet, 4,600-4,690 feet, and 5,480-5,550 feet (fig. 2).

Loose sands

The loose sands in cuttings of the Mesa 6-2 drillhole can be categorized into three groups, based on grain size and degree of rounding. In figure 2, Group 1 and Group 3 are shown separately; Group 2 is not differentiated. Loose sands are abundant below 3,550 feet in Mesa 6-2.

(1) Group 1 includes angular or sub-angular grains of quartz and some feldspar. The grains are coarse or very coarse-grained (>0.5 mm, generally >1.0 mm). This category, in conjunction with Group 2, is equivalent to the "monomineralic fragments" described in the open-file report on Mesa 6-1 (Fournier, 1973, p. 13 and p. 17), except that in Mesa 6-2 calcite rhombs are extremely rare. (See p. 14 in this report.)

(2) Group 2 includes subrounded to rounded quartz grains, dominantly fine-grained, with some medium-grained material. At available magnifications (30X), many of these appear to be finely pitted or frosted. Grains of this type are present in many samples, but always in amounts less than 10 to 15 percent of the cuttings sample, and rarely more than 5 percent, even in intervals which contain much sand. Similar fine-grained, rounded sand grains, also in small amounts, were found in the cuttings of the Mesa 6-1 drillhole. According to W. A. Elders (written commun., 1975), these grains appear to be surface sands which contaminated the cuttings during drilling. This would account for the random distribution of the grains in the cuttings.

(3) Group 3 includes subrounded to subangular, fine to medium-grained sand grains, generally fairly well sorted and commonly white or clear. This is the most abundant type of loose sand in the cuttings from the Mesa 6-2 drillhole; it comprises as much as 95 percent of some samples. Locally, the loose sand is more poorly sorted, ranging from silt to medium or coarse-grained sand, and including some more angular grains. Included in Group 3, "loose sand," are some large chunks (up to 40 mm diameter) of very loosely cohering sand, commonly poorly sorted

and subangular to angular, which crumble readily between the fingers. The cementing material is at least in part carbonate which is readily soluble in dilute HCl.

Other rock types

Green clay-rich material

Aggregates of pale green, very fine-grained material with indented surfaces, described from the cuttings of the Mesa 6-1 drillhole, are also found in the cuttings of the Mesa 6-2 drillhole. Here they occur sporadically, and can be visually distinguished throughout the depth interval below 2,400 feet. There is no zone in which they are particularly abundant. No X-ray study was made of these fragments from Mesa 6-2, because similar samples from Mesa 6-1 had been studied by X-ray diffraction and found to be composed of illite, quartz, and traces of calcite (Fournier, 1973).

Chlorite-rich fragments

These polymineralic, dark-green grains are notably less common in the cuttings of the Mesa 6-2 drillhole than in those of the Mesa 6-1 drillhole. X-ray study of four hand-separated grains, from depths ranging from 3,200 to 5,340 feet, shows that they vary in composition: at 3,200 feet--chlorite, albite, quartz, muscovite; at 4,540 feet--chlorite, quartz, K-feldspar, calcite, dolomite; at 4,700 feet--chlorite and muscovite; at 5,340 feet--chlorite, albite, quartz, pyrite, K-feldspar, illite, calcite, and dolomite. As in Mesa 6-1, the chlorite is a well-crystallized, probably magnesium-rich chlorite, with 7Å:14Å ratios varying from more than 3:1 to 5:1, and a strong 14Å diffraction maximum, which shifts to smaller d-spacings (higher $°2\theta$) after heating at 550°C for 1 hour. This chlorite is quite different from the chlorite in the siltstones and sandstones. (See section on Chlorite, in MINERALOGY, p. 22-23).

Other types of rock fragments, both igneous and metamorphic, are less common in cuttings from Mesa 6-2 than in those from Mesa 6-1. Their distribution is summarized in table 3.

Black lustrous fragments

Black fragments are found in many intervals throughout the section. A zone composed of about 50 percent black fragments is found at 700-710 feet. Lower in the section black grains are most abundant (up to 5 percent of the cuttings) in intervals between 3,390 and 3,550 feet. The five samples from depths between 3,500 and 5,625 feet were amorphous to X-rays or showed only quartz peaks superimposed on an amorphous background. To test for amorphous sulfur, twelve samples were heated in glass tubes sealed at one end; all tests were negative. This is in contrast to the results obtained from the black shiny grains from the Mesa 6-1 drillhole, where amorphous sulfur was detected by this method at four different depth intervals. Moreover, the two samples of black grains from Mesa 6-2 which appeared most like the amorphous sulfur grains of Mesa 6-1 were insoluble in carbon disulfide (CS_2). Three other samples of black grains were immersed in sodium hypochlorite (5 percent) for 48 hours at room temperature; this treatment partially bleached the grains and reduced them to a pulpy consistency. It is concluded that the black grains in the Mesa 6-2 drillhole are dominantly composed of organic material, which may be indigenous, or may have been introduced during drilling.

Table 3.--Distribution of miscellaneous minor rock types (as rock fragments and pebbles)

Depth interval (feet)	
80-90	Large pebble: diorite (?)
100-120	Pebbles: diorite
140-160	Pebbles: quartz, dark fine-grained rock
290-300	Biotite granodiorite, large piece 14 mm in diameter
320-330	Quartz pebble, large, 14 mm diameter
380-390	Pebbles: granitic rock
410-420	Pebbles: granitic rock
420-430	Pebbles: gneissic granite, quartz
440-450	Pebbles: quartz
460-470	Many large pebbles: some granitic
470-480	Many pebbles (>60): most quartz and quartzite, some granitic, some metamorphic, some volcanic
480-490	Many pebbles: most quartz, some granitic, some amphibolite
490-510	Pebbles: granitic, some quartz
550-560	Pebbles: quartz
600-610	Pebbles: volcanic, granitic
650-660	Many pebbles: volcanic (felsic), granitic, quartz, quartzite
700-710	Pebbles: quartz, granitic
820-830	Pebbles: quartz
830-840	Pebbles: amphibolite (up to 14 mm), pink rhyolite
840-850	Pebbles: quartz, plutonic igneous
850-860	Pebbles: granitic rock, quartz

Table 3.--Distribution of miscellaneous minor rock types (as rock fragments and pebbles)--Continued

Depth interval (feet)	
860-870	Pebbles: granitic rock, pink rhyolite
870-880	Pebbles: quartz
890-900	Pebbles: quartz, granite, dark volcanic porphyry
900-910	Pebbles: amphibolite gneiss, quartzite, granitic rock
910-920	Pebbles: granitic, coarse-grained amphibolite, dark volcanic porphyry
930-940	Pebbles: granitic, large (up to 7 mm), one with zoned plagioclase; dark volcanic; quartzite
940-950	Pebbles: granitic, graphic granite, quartzite, purple rhyolite
950-960	Pebbles: granitic, quartzite
960-980	Pebbles: dioritic, quartz
990-1,000	Pebbles: quartz, granitic
1,000-1,010	Pebbles: quartz, quartzite, granitic
1,020-1,030	Pebbles: quartz, granitic, volcanic
1,030-1,040	Pebbles: granitic, amphibolite
1,060-1,070	Pebble: felsite
1,100-1,110	Many pebbles: most quartz; some granitic
1,110-1,120	Pebbles: granitic, red volcanic porphyry, quartz
1,120-1,130	Many pebbles: quartz of various colors, granitic, felsic volcanic, biotite schist
1,130-1,140	Pebbles: quartz, granitic
1,180-1,190	Pebbles: quartz

Table 3.--Distribution of miscellaneous minor rock types (as rock fragments and pebbles)--Continued

Depth interval (feet)	
1,210-1,230	Pebbles: quartz, granitic, volcanic, biotite schist
1,230-1,240	Pebbles: quartz, granitic, basalt (?)
1,240-1,250	Many pebbles: most are quartz, also pink rhyolite, graphic granite, mica schist, fine-grained micaceous gneiss, quartzite
1,250-1,260	Many pebbles: most are quartz; many pink rhyolite, schist
1,260-1,270	Pebble: purple porphyritic rhyolite (8 mm)
1,270-1,280	Few pebbles: quartz
1,480-1,490	Few pebbles: basalt, felsite porphyry
1,520-1,530	Many pebbles: quartz, quartzite, rhyolite of varying colors, pumice, breccia, basalt (?)
1,830-1,840	Many pebbles (>100), about 10 percent of sample: most quartz, some quartzite, granitic, volcanic
1,840-1,850	Many pebbles: most quartz, also quartzite, gneiss
1,850-1,860	Few pebbles: quartz, light gray volcanic
1,860-1,870	Few pebbles: quartz
	No pebbles between 1,870 feet and 2,880 feet
2,880-2,890	Pebble: red rhyolite porphyry
2,890-2,900	Fragment: yellow quartzite
2,910-2,920	Fragment: breccia with black veinlets

Table 3.--Distribution of miscellaneous minor rock types (as rock fragments and pebbles)--Continued

Depth interval (feet)	
2,920-2,930	Fragment: fine-grained black and white rock, metamorphic or igneous
2,940-2,950	Fragment: fine-grained black and white rock, metamorphic or igneous
2,970-2,980	Fragment: gray and white metamorphic with white mica
3,200-3,210	Fragment: chlorite-quartz rock
3,220-3,230	Pebbles: quartz, granitic
3,230-3,240	Pebble: granitic
3,240-3,250	Fragments: granitic, chlorite-quartz-feldspar metamorphic rock
3,290-3,300	Fragment: granitic
3,310-3,320	Fragment: feldspar-quartz-chlorite rock
3,320-3,330	Fragment: granitic
3,490-3,500	Fragment: rhyolite breccia with sulfide veinlet
3,540-3,550	Fragment: pink granitic rock
3,730-3,740	Fragments: coarse-grained chlorite-feldspar grain
3,800-3,810	Fragments: pink granitic; chlorite-rich rock
3,820-3,830	Fragment: chlorite-rich metamorphic rock
4,000-4,010	Fragment: granitic rock with coarse mica
4,010-4,020	Fragment: green metamorphic rock, containing quartz, plagioclase, chlorite, pyrite
4,200-4,210	Fragment: chlorite-quartz rock
4,310-4,320	Fragments: chlorite-rich metamorphic rocks, one with pyrite

Table 3.--Distribution of miscellaneous minor rock types (as rock fragments and pebbles)--Continued

Depth interval (feet)	
4,540-4,550	Fragments: quartz-chlorite-pyrite rocks with calcite, illite, plagioclase
4,640-4,650	Fragment: red volcanic
4,800-4,810	Fragment: greenschist
4,930-4,940	Fragment: rhyolite
4,970-4,980	Fragment: chlorite-quartz-pyrite rock
4,990-5,000	Fragments: rhyolite, chlorite-rich metamorphic rock
5,290-5,300	Fragments: chert, quartz-chlorite rock
5,340-5,350	Fragment: quartz-chlorite-pyrite-K-feldspar rock
5,470-5,480	Pebble: granitic (10 mm diameter)
5,560-5,570	Fragment: granitic
5,600-5,610	Fragment: granitic
5,660-5,670	Fragment: volcanic porphyry
5,670-5,680	Fragment: schist

Fossils (?)

A few freshwater gastropods, similar to those found in the cuttings from Mesa 6-1 between 400 and 1,630 feet (Fournier, 1973) were found in the Mesa 6-2 drillhole between 400-430 feet and 550-560 feet, but were considerably less abundant than in the Mesa 6-1 drillhole.

LITHOLOGIC UNITS OF POSSIBLE USE FOR CORRELATION

Distinctive horizons are rare in the Mesa 6-2 drillhole. As may be seen from figure 2, there are three zones which are dominantly composed of loose sand, particularly the region between 3,840 and 4,370 feet (or 4,550 feet if one includes Group 1 sands), and two zones in which sandstone fragments are especially abundant. However, these sand and sandstone horizons do not correlate with sand-rich horizons (horizons poor in siltstone)in the Mesa 6-1 drillhole (fig. 3), and in any case, it is doubtful whether the lateral extent of such sand horizons would be very great. It is also not known how accurately the cuttings samples reflect the section; as will be discussed in the final section (p. 53-55), there is some evidence that much of the loose sand may have sloughed downward considerable distances.

In the cuttings of the Mesa 6-1 drillhole, there is a horizon at 990-1,120 feet in which 80 percent of the cuttings samples is composed of pebbles (1-8 mm in diameter). Most of these are quartz, although minor amounts are feldspar, chlorite-rich metamorphic grains, granitic rock, and rhyolite (volcanic rock). Above this pebble zone, 130 feet of cuttings are missing. It was hoped that a comparable pebble zone might be detected in the Mesa 6-2 drillhole, but the pebble concentrations at 460-490 feet, 600-660 feet, 940-1,000 feet, and 1,100-1,120 feet are greatly reduced. Even in the most prominent pebble-rich horizon at 1,830-1,850 feet, pebbles comprise only 10 percent of the cuttings. The pebbles are, however, of the same type as in the pebble horizon of Mesa 6-1: dominantly quartz, some quartzite of various colors, and some granitic and volcanic rocks. There is a possibility that in Mesa 6-1, the pebbles had been concentrated by washing away the silt and mud at the drill site, whereas in Mesa 6-2, because of the difficulty of washing away the mud, the pebbles were less concentrated. But if this is so, then the major pebble zone is 850 feet deeper in Mesa 6-2 than in Mesa 6-1.

In the Mesa 6-1 drillhole, a surface of discontinuity at 2,500-2,600 feet is marked by changes in color of some siltstones and by a change in the habit of the visible calcite. No similar change is found in the Mesa 6-2 drillhole; all four siltstone color types are found from 2,550 to 6,000 feet, and almost all visible calcite is fibrous throughout the section. (Buff, light gray, and red siltstone occur at depths as shallow as 1,600 feet, but colors cannot be distinguished in every sample because of adhering mud and silt.) There is, however, a great change in the degree of consolidation of the cuttings material at about 2,500-2,600 feet. There is also a discontinuity in the distribution of montmorillonite in this depth interval. Above 2,000 feet, it is found in all rock types; between 2,000 and 2,300 feet it is absent from the buff siltstone and present only in very small amounts in light gray and red siltstones. Between 2,300 feet and 2,600 feet montmorillonite is absent from all siltstone types, and from 2,600 feet to the bottom of the hole it is found only in the buff siltstone. These discontinuities could reflect, as postulated for the Mesa 6-1 drillhole, a difference in type of circulation above and below the 2,500-2,600-foot level. Or the material above 2,500-2,600 feet may have been deposited in a basin under different conditions from the deeper material and the material from Mesa 6-1. There is no conclusive evidence for or against the existence of, or amount of, displacement of the postulated fault drawn between the two drillholes, since no definite marker horizons have been found. The variations in distribution of montmorillonite are puzzling, and may reflect the superposition of two sets of conditions at different times.

CORRELATIONS OF LITHOLOGY WITH POROSITY

Despite the presence of extensive sand-rich zones, there is very poor correlation between the lithology as determined by visual inspection of each cuttings sample and the percent clay as interpreted from the electrical logs (U.S. Bureau of Reclamation, 1973c). The comparison was made in two ways: (1) by comparing the percentage of siltstone in the cuttings samples to the percentage of clay as interpreted from the electrical logs; and (2) by comparing the percentage of loose sand (Group 3) in the cuttings samples to the percent porosity, to the percent matrix, and to the sum of porosity and matrix as interpreted from the electrical logs. In none of these cases is there a good correlation. Nor is it possible to achieve correlation by assuming that the cuttings depth is in error by 10 to 40 feet in either direction and by displacing the cuttings log up or down the hole with respect to the electrical log.

Where the electrical log depicts an interval of 50 to 100 feet with low clay content and high matrix percentage, there is a pattern which occurs in 9 of 20 cases (using only data below 2,600 feet, where there are good lithologic data). The loose sand content in these nine cases is low throughout most of the interval, but is high in the bottom 10 to 20 feet of the interval. For example, in the interval 3,600-4,000 feet, matrix is 70-80 percent (and clay less than 5 percent) over most of the interval. Loose sand percentages, in successive 10-foot intervals from top to bottom, read 0, 1, 8, and 65 percent. However, this pattern is not consistently present. For example, in the interval 4,240-4,270 feet, where clay is 40 to 80 percent and matrix is 20-40 percent, loose sand percentages, from top to bottom, read 2, 90, and 95 percent; but in the next interval down the hole, 4,270-4,400 feet, where clay is about 5 percent and matrix 50-80 percent, loose sand percentages, from top to bottom, read 90, 90, 0, 12, 10, 6, 3, 62, 15, 85, 95, 95, and 95 percent. In conclusion, in about half the depth intervals with low clay and high matrix, the lithology can be accounted for by sloughing of loose sand downward, but the data do not support this idea in all depth intervals.

It seems from this study that the prospects of attaining correlations between geophysical logs and stratigraphic logs based on cuttings, rather than core, are very poor in this geologic environment, even when the cuttings are sampled every 10 feet. Mineralogical data, the detection of mineralogical changes where they occur, and a general idea of what rock types are present are the data that can be obtained. Correlation between drillholes on the basis of lithology is not promising in this particular region of alternating thin-bedded siltstones and sandstones, as there are no distinctive and areally extensive marker horizons with which lateral correlations can be made.

REFERENCES CITED

Bailey, S. W., and Brown, B. E., 1962, Chlorite polytypism: I. Regular and semi-random one-layer structures: Am. Mineralogist, v. 47, p. 819-850.

Borg, I. Y., and Smith, D. K., 1968, Calculated powder patterns: I. Five plagioclases: Am. Mineralogist, v. 53, p. 1709-1723.

Bradley, W. F., 1954, X-ray diffraction criteria of chloritic material, in Clays and Clay Minerals: Washington, D. C., Natl. Acad. Sci.-Natl. Research Council Pub. 327, p. 324-334.

Brindley, G. W., and Ali, S. Z., 1950, Thermal transformations in magnesian chlorites: Acta Cryst., v. 3, p. 25-30.

Carroll, Dorothy, 1970, Clay minerals: a guide to their X-ray identification: Boulder, Colorado, Geol. Soc. America Special Paper 126, 80 p.

Fournier, R. B., 1973, An X-ray and optical study of cuttings from the U.S. Bureau of Reclamation Mesa 6-1 drillhole, Imperial Valley, California: U.S. Geol. Survey Open-File Report, 35 p.

Garcia, S. G., and Camazano, M. S., 1968, Differentiation of kaolinite from chlorite by treatment with dimethyl-sulphoxide: Clay Minerals, v. 7, p. 447-450.

Grim, R. E., 1968, Clay Mineralogy: New York, McGraw-Hill, 596 p.

GSA Rock-Color Chart, 1963, New York, Geological Society of America.

Hayes, J. B., 1970, Polytypism of chlorite in sedimentary rocks: Clays and Clay Minerals, v. 18, p. 285-306.

Merriam, Richard, and Bandy, O. L., 1965, Source of upper Cenozoic sediments in Colorado delta region: Jour. Sed. Petrology, v. 35, p. 911-916.

Muffler, L. J. P., and Doe, B. R., 1968, Composition and mean age of detritus of the Colorado River delta in the Salton Trough, southeastern California: Jour. Sed. Petrology, v. 38, p. 384-399.

Muffler, L. J. P., and White, D. E., 1969, Active metamorphism of upper Cenozoic sediments in the Salton Sea geothermal field and the Salton Trough, southeastern California: Geol. Soc. America Bull., v. 80, p. 157-182.

Shirozu, Haruo, 1962, Thermal reaction of iron chlorites: Clay Science, v. 1, no. 5, p. 108-113.

Swanberg, C. A., 1973, Preliminary results of geothermal well Mesa 6-2, Mesa Anomaly, Imperial Valley, California [abs.]: Am. Geophys. Union Trans., v. 54, no. 11, p. 1215-1216.

U.S. Bureau of Reclamation, 1973a, Drilling geothermal well Mesa 6-2, Specifications No. 300C-336.

_____1973b, Test well Mesa 6-1: Geothermal Resource Investigations, Special Report, 44 p.

_____1973c, Schlumberger synergetic log systems computer processed interpretation, SARABAND, a sandstone analysis, for well no. Mesa 6-2.

van de Camp, P. C., 1973, Holocene continental sedimentation in the Salton Basin, California: a reconnaissance: Geol. Soc. America Bull., v. 84, p. 827-848.

96-88

EXPLANATION

The percentage of each lithologic unit in the cuttings sample is indicated by the height of the bar in each depth interval.

100
50
0

• (dot) indicates that the lithologic unit is present in amounts less than 2 percent

In the "Loose sands" column,
■ = Group 1
□ = Group 3
(see text)

Figure 2. Distribution and abundance of lithologic units in Mesa 6-2

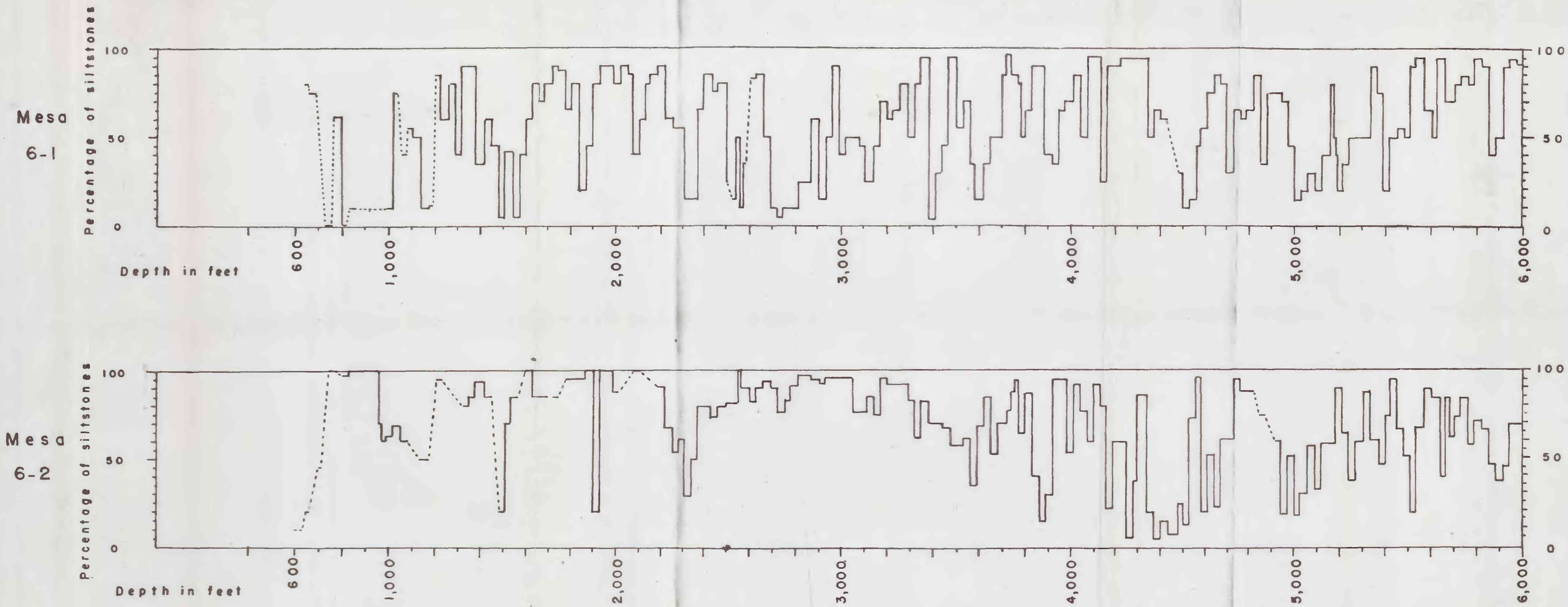

Figure 3. Percentages of siltstones in Mesa 6-2 compared with Mesa 6-1

The height of the bar in each depth interval is proportional to the sum of the percentages of the four types of siltstone present in the cuttings from that well. For Mesa 6-2, values were averaged over depth intervals corresponding to those for which data are available from Mesa 6-1, generally 30 feet.

76-88

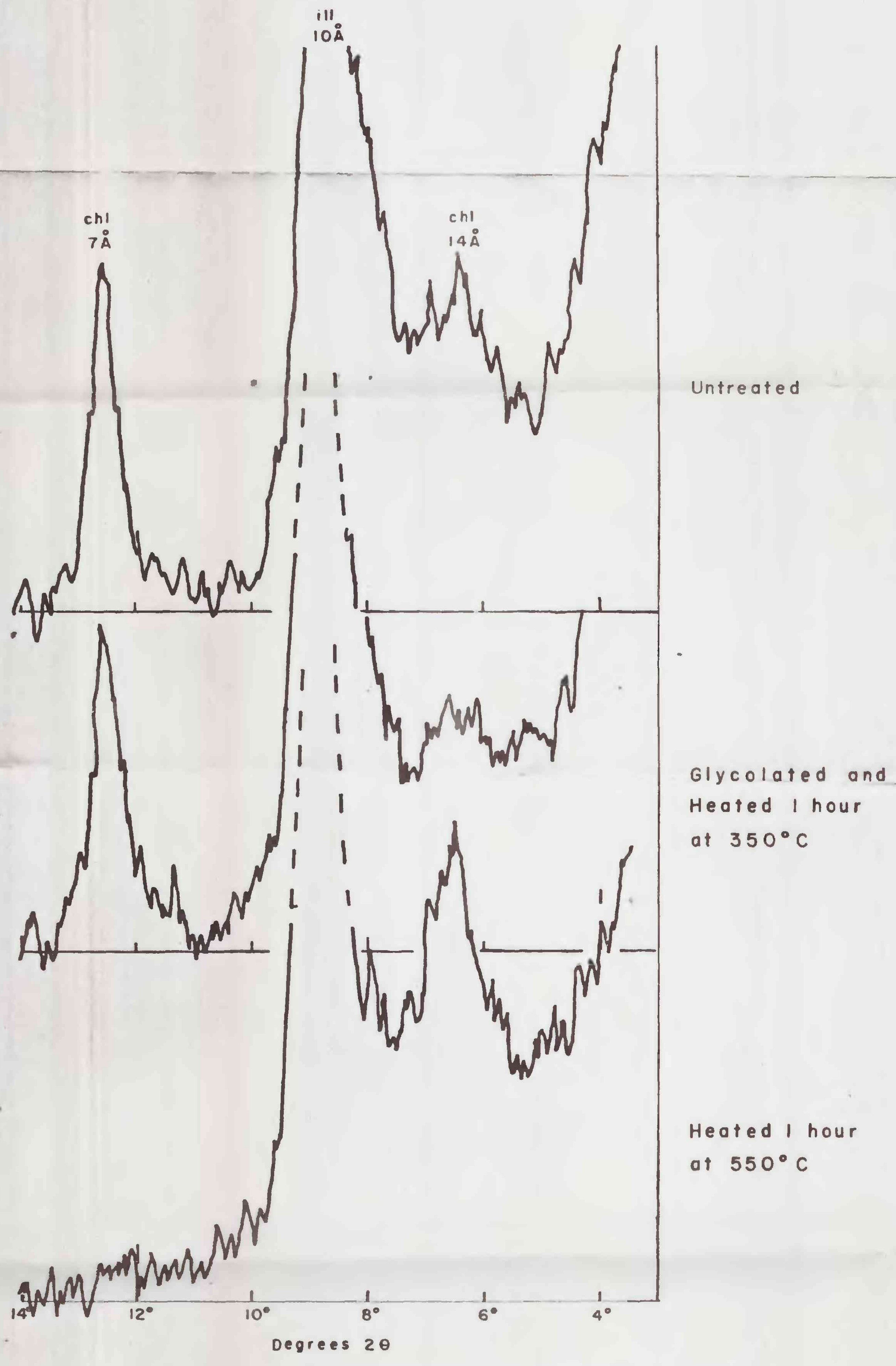

Fig. 4A. Light gray siltstone, from 2,600 feet

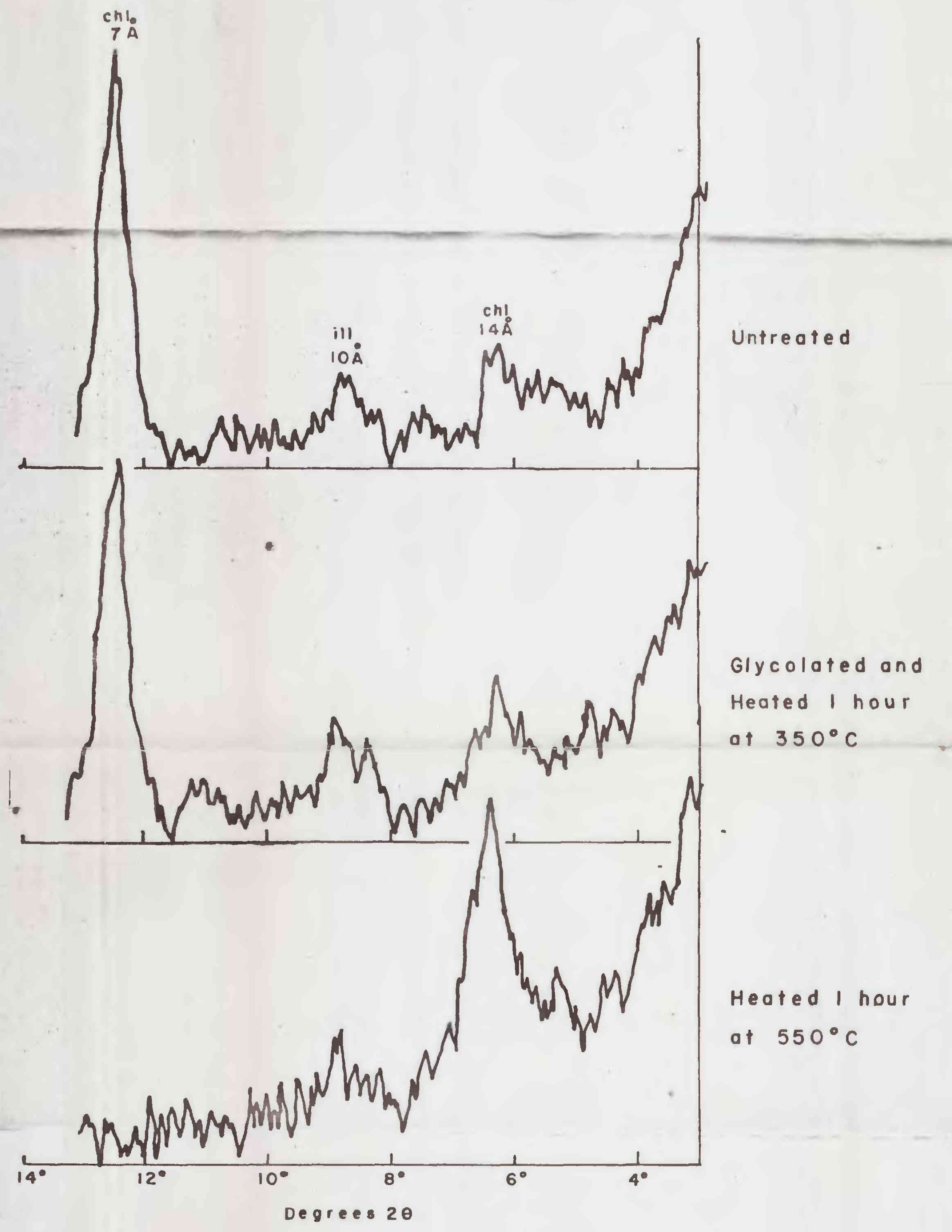

Fig. 4B. Light gray silty to very fine-grained sandstone with dark brown chlorite, from 5,030 ft.

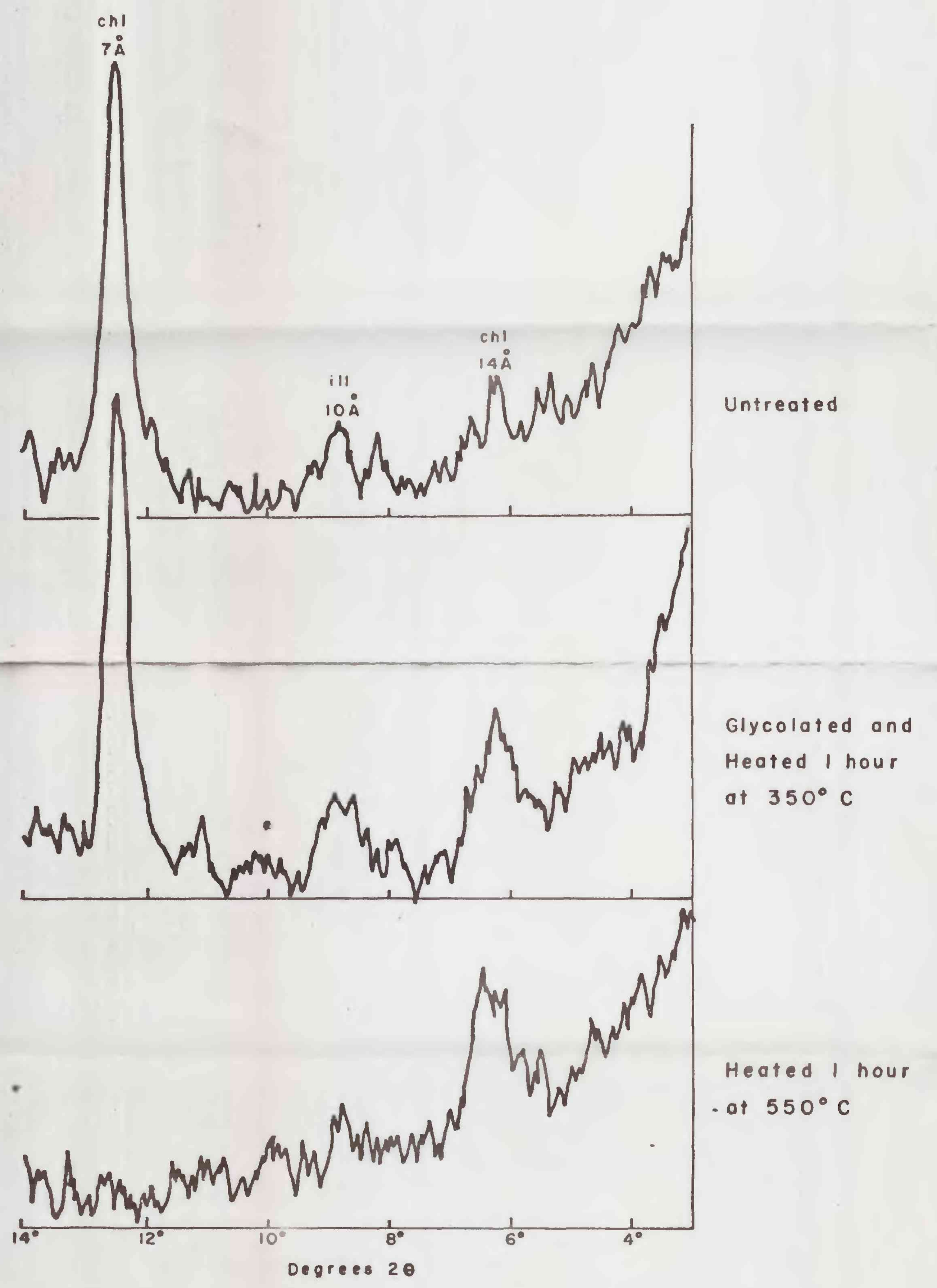

Fig. 4C. Buff very fine to fine-grained sandstone with platy green chlorite, from 5,290 feet.

76-88

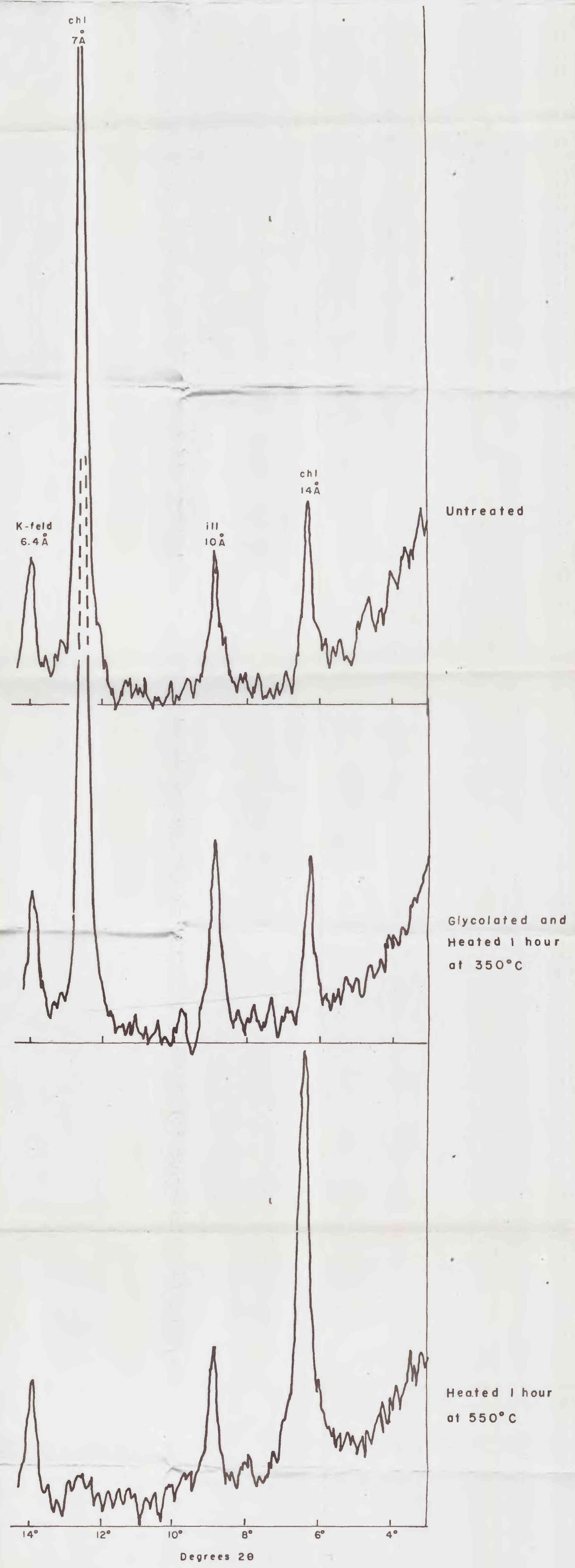

Fig. 4D. Chlorite in fragment of metamorphic rock, from 3,200 feet

Figure 4. X-ray diffraction patterns of chlorite in different rock types