CLIMATIC CHARACTER OF THE INTERVAL BETWEEN THE JURASSIC AND CRETACEOUS IN NEW MEXICO AND ARIZONA

LUNA B. LEOPOLD
Albuquerque, New Mexico

ABSTRACT

In many places in New Mexico and Arizona a kaolinized, white horizon has been noted at the top of the Morrison formation (Jurassic) immediately under the Dakota (Cretaceous). In general, this is kaolin-cemented, white sandstone, but in Rio Arriba County, New Mexico, there occurs a nearly pure, white, massive kaolinite in small lenses at the contact between the formations.

The kaolinization is of such widespread distribution that it may be useful as a horizon-marker in drilling operations, and it indicates that a moist climate prevailed during a part, at least, of the time between Jurassic and Cretaceous deposition in this area.

INTRODUCTION

The upper Jurassic in New Mexico and Arizona is represented by the Morrison formation,[1] and the upper Cretaceous by the Dakota formation. The interval between represents a relatively long period of subaerial weathering and a change from fresh-water to marine deposition. The occurrence of kaolin in small lenses at various localities where the contact between the formations is exposed, and the widespread distribution of a kaolin-cemented sandstone at the contact, afford some new evidence on the climate of the interval.

THE OCCURRENCE OF KAOLIN

On Mesa Alta in the southeast portion of Rio Arriba County, New Mexico, west of the Rio Chama and just north of the Rio Puerco (del Oriente), the upper beds of the Morrison formation consist of buff-colored, medium-grained sandstone interbedded with a few thin lenses of conglomerate. The latter consists of well-rounded pebbles of quartzose or feldspathic material, $\frac{1}{8}$–2 inches in diameter, the feldspars concentrically weathered to a chalky consistency. Both the gravelly phase and the buff sandstone are cross-bedded at least in places and for the most part constitute a slope-forming member of the formation.

The overlying Dakota in this locality is a brown to buff-colored, medium-grained sandstone conspicuously cross-bedded and includes gravelly phases similar to those in the Morrison. The Dakota is well cemented and definitely a cliff-forming member.

In the Mesa Alta locality the contact between the Morrison and Dakota formations is distinctively marked by the presence of kaolin. The kaolin occurs in some outcrops as a lens of massive kaolinite, in other outcrops as a part of the cement in a white sandstone. In still other places the kaolin is present as a sandy white clay interbedded with thin layers of white sandstone or, less commonly, with lenses of limestone. The character of the zone containing kaolin varies sharply within short horizontal distances.

Massive kaolinite occurs on the west hillside overlooking the Cañada del Ca-

[1] Nomenclature clarified by A. A. Baker, C. H. Dane, and J. B. Reeside, Jr., "Correlation of the Jurassic Formations of Parts of Utah, Arizona, New Mexico, and Colorado," *U.S.G.S. Prof. Paper 183* (1936).

mino, one of the grassy valleys draining the top of Mesa Alta. The deposit is approximately 1 mile north of the south escarpment of Mesa Alta and about 12 miles by road northwest of the village of Youngsville. Here the basal 15 feet of the Dakota sandstone contains no trace of the kaolinitic cementing material. The contact with the underlying Morrison dips slightly to the east at about 1.5 feet per 100, but the two formations are parallel. Immediately under the Dakota is a ½-inch layer of white, soft, clayey sand which grades downward into a sandstone cemented by kaolinitic material. This sandstone, in turn, grades into gray sandstone which in places contains small inclusions of smooth, gray kaolinite. This grades into a smooth homogeneous, gray kaolin, pure except for some grains of quartz, and this, in turn, into a pure, white, massive kaolinite which, though easily scratched with a knife, gives the appearance of being more slaty than chalky. From the base of the Dakota to the base of the white kaolinite is about 7 feet.

Underlying the kaolinite and separated by a well-defined joint plane is a white sandstone cemented by kaolin. Within a vertical distance of 15 feet this grades into a buff, cross-bedded sandstone typical of the upper Morrison of this locality.

The section just described has been exposed by hand quarry operations, but owing to the soil mantle it is difficult to determine the exact shape of the deposit. It appears to be in the form of a lens extending approximately 300 feet in a north-south direction along the outcrop. The lens extends an unknown distance west into the ridge, but on the west slope of the ridge, a straight-line distance of about ½ mile, the white kaolin does not occur. Instead, there is a gray kaolinite, which is pure except for the inclusion of some quartz grains, and which turns nearly white when dried. Outcrops of the contact on ridges lying east of the main deposit of the Cañada del Camino show an impure white kaolin interbedded in places with sandstone, the grains of which are cemented with kaolinitic material.

The writer has inspected samples of a pure white kaolin from two other deposits—one on Mesa Alta about 5 miles east of the Cañada del Camino, the other roughly 4 miles south of the village of Coyote and 9 miles southeast of the main deposit already described. The kaolin of these samples is practically identical with that in the quarry.

FIG. 1.—Massive kaolin in quarry, Cañada del Camino, Mesa Alta.

In the main quarry the white kaolin has an irregular joint pattern, the best developed set striking N. 21° E., dipping 81° W. and 4–8 inches apart. A less well-defined vertical set of joints strikes N. 69° W. Horizontal jointing probably related to weathering is also apparent.

Figure 1 is a photograph of the kaolin in the main deposit where quarrying has exposed the section. The joint planes are coated with a blackish varnish, probably a manganese salt deposited from ground water. Figure 2 shows the kaolinitic sandstone 1 mile southeast of the main quarry.

FIG. 2.—Dakota overlying Morrison white, chalky sandstone cemented with kaolin, near south escarpment of Mesa Alta.

A microscopic examination of the white kaolin showed it to be nearly pure kaolinite. A chemical analysis of the same material gave the results[2] shown in Table 1. Microscopic examination of the

TABLE 1

	Per Cent
Silica	46.82
Alumina	38.11
Magnesia	.09
Lime	.17
H_2O at 105° C.	.36
H_2O above 105° C.	13.46
Total	99.01

gray kaolin of the outcrop ½ mile east of the Cañada del Camino quarry showed that it is composed mostly of kaolinite with quartz grains which were included when the kaolin was deposited.

OTHER OCCURRENCES OF THE KAOLINIZED ZONE

The contact between the Morrison and Dakota formations was examined in many localities in northwestern New Mexico. Except for the three outcrops on and near Mesa Alta, no occurrence of pure white kaolin was found; but at nearly all the sections inspected the contact between the two formations is characterized by a whitened layer, in most places sandstone, the cementing material of which is white and of a kaolinitic composition. The whitened zone is very distinctive at Mesa Alta, in outcrops near the Arroyo Salado in the Nuestra Señora de la Luz de Lagunitas Grant,[3] near the confluence of the Rio Puerco and Rio San Jose near Suwanee, at Inscription Rock (El Morro National Monument), and south of Las Vegas, New Mexico. Field work did not extend to outcrops of the Comanche series in eastern New Mexico.

The stratigraphy of sections through the contact varies from one place to another. Table 2 gives descriptions of sections from different localities.

Channeling of the upper Morrison beds has been noted in a number of localities, but the maximum relief in outcrops east of Gallup, New Mexico, apparently does not exceed a few feet. Figure 3, photographed in the Lagunitas Grant near the Arroyo Salado, shows channeling in the white to greenish, shaly clay of the uppermost Morrison. The overlying Dakota is a medium- to coarse-grained sandstone, mostly of subangular

[2] Microscopic examination by Cornelius S. Hurlbut, Jr., Harvard University. Identification on the basis of index of refraction.

Chemical analysis by Earl Emendorfer, New York City, at request of Dr. Paul F. Kerr.

[3] Location near Francis' Ranch, as shown near center of Plate 19, C. B. Hunt, "Geology and Fuel Resources of the Southern Part of San Juan Basin, New Mexico," *U.S.G.S. Bull. 860-B*, Part II (1936).

TABLE 2

	Feet
Cañada del Camino, Mesa Alta, north of Youngsville, N.M.:	
Cross-bedded brown to buff, medium-grained sandstone, conglomeratic in places (Dakota)	15
White, soft sandstone, grains cemented with kaolin grading into pure white massive kaolinite (Morrison)	7
White sandstone cemented with kaolin grading abruptly into buff, medium-grained sandstone with local lenses of quartzitic and feldspathic conglomerate	10
West face, Mesa de los Viejos, north of Abiquiu, N.M.:	
Thin-bedded, buff, quartzose, sandstone, cross-bedded	15
Gray quartzose sandstone with large fragments of carbonaceous material, mostly lignite (Dakota?)	7
White quartz sandstone, cemented with white clay material, weathering to caves (Morrison?)	10
Massive white sandstone, no white clay between grains, cross-bedded in lower part	10
Near Arroyo Salado, Lagunitas Grant south of Cabezon, N.M.:	
Carbonaceous shale	1
Thin-bedded sandstone with layers of carbonaceous shale, mostly lignite (Dakota?)	8
Massive white sandstone, bands of limonite staining, grains quartzose, subrounded to subangular, subrounded with white powdery clay (Morrison?)	25
Light green claystone	$1\frac{1}{2}$
White sandstone, some white clay between grains	3
Near Window Rock, Arizona:	
Shaly sandstone with thin carbonaceous layers	6
Shaly lignite (Dakota?)	2
White medium-grained sandstone, cemented with white clay; conglomeratic and cross-bedded at base (Morrison?)	15
Hematite stained medium-coarse grained sandstone containing conglomeratic phases	100

grains of quartz, cemented by a white material, and including a few concretionary fragments of the underlying

FIG. 3.—Contact of Morrison greenish-white, shaly clay beneath the overlying Dakota sandstone. Note channeling. Lagunitas Grant near Arroyo Salado.

FIG. 4.—White kaolin in small channels just below contact of Morrison and Dakota, near Suwanee, New Mexico.

Morrison. Figure 4, photographed near Suwanee at the confluence of the Rio San Jose and Rio Puerco, shows channels of nearly pure kaolin occurring in a greenish clay full of gypsum crystals, the latter probably recent crystallization from ground water. The overlying Dakota is a buff conglomeratic sandstone. The greenish clay rapidly fell apart when immersed in water.

Parry Reiche describes the section 6 miles north of the northern escarpment of Waterless Mesa and 20 miles west of Chinle, Arizona: "At the top of the Morrison . . . . is a dead white, very coarse, cemented, ill-sorted sandstone precisely like that on the top of Inscription Rock" (El Morro National Monument) south of Grants, New Mexico. The white sandstone above "is characterized by angular, coarse grains which resemble chalk, probably kaolinized feldspar. . . . . Below this sandstone is a buff to light brown, coarse, ill-sorted subangular to subrounded sandstone, fairly well-cemented, with low-angle cross-bedding and much channeling."[4]

From this description it appears that the old surface increased in relief to the west, but decomposition of feldspathic material into clays, leached to a light color, also prevailed in this area.

The white zone of kaolin-cemented sandstone, though widespread in its occurrence, may be, in certain places, not a distinctive feature and may be too thin to show itself in well cores with certainty. However, the general features of the contact between the two formations as described in this study give some new cri-

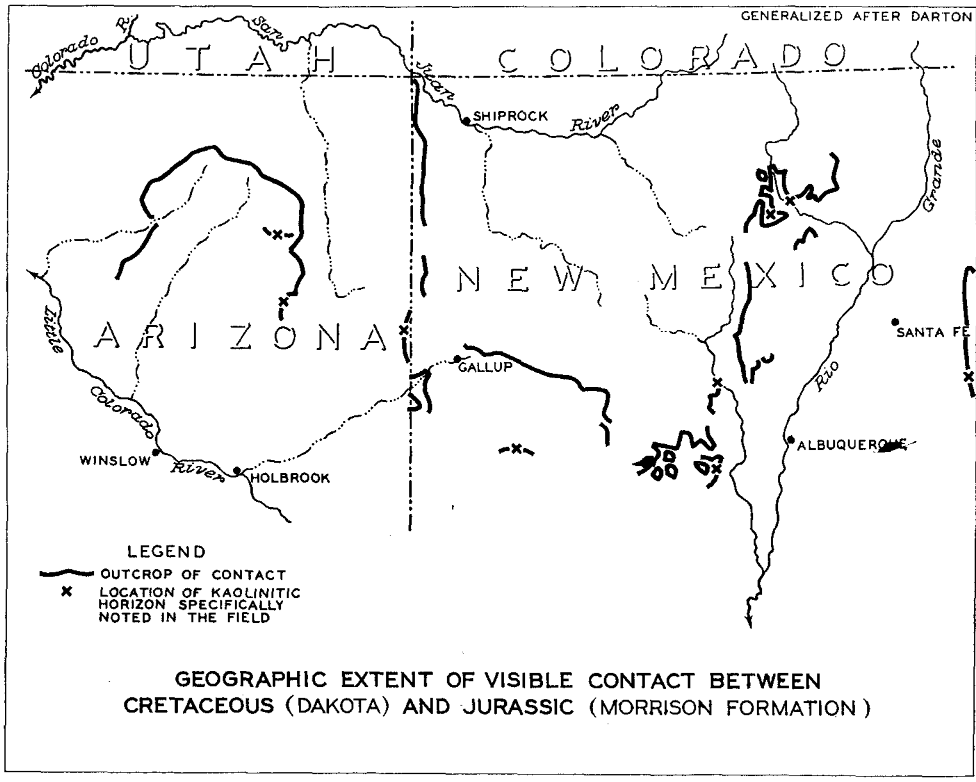

FIG. 5.—Generalized map showing linear extent of outcrops where contact of Jurassic and Cretaceous is exposed. Observations at Steamboat and Waterless Mesa, Ariz., and Chapelle, N.M., by Parry Reiche, unpublished notes.

[4] Unpublished notes.

teria which may be useful in search of a horizon-marker in drilling operations. Table 3 gives descriptions of cuttings from a well drilled by the Ambrosia Company north of Grants, New Mexico. Only that section of the log near the contact of Dakota and Morrison is described.

TABLE 3

WELL LOG, AMBROSIA COMMITTEE NO. 1, SE¼, SEC. 11, T 14 N, R 10 W, MCKINLEY COUNTY, N.M.; DRILLED WITH CABLE TOOLS

	Feet
Fine, clean, white quartz sand; occasional lignite fragments with numerous coal fragments	135– 45
Gray, ill-sorted, silty sandstone	145– 55
Gray, sorted, very fine sand and abundant argillaceous lignite	155– 85
Light greenish gray, soft claystone	185–205
Same, with abundant quartz grains	205– 15
Same, about half the claystone fragments dull maroon	215– 25

In this well the Dakota formation persists to a depth of 185 feet, and the upper Morrison probably begins at this depth. The greenish claystone is similar to that in outcrops near the Arroyo Salado. No layer of kaolin-cemented sand is apparent at the contact in this well.

The log indicates that the kaolin is not everywhere present at the contact, as certain outcrops show, and in places a white clay-cemented sandstone may occur in the Morrison, well below the contact. This does not necessarily rule out the possibility of using the kaolin as a marker-bed in other localities. Erosion on the old surface may have removed any traces of kaolinization. The sandstone member of the upper Morrison does not occur in some localities and is represented by shaly beds. The kaolinization is apparent only where the sandstones exist and probably is not a characteristic feature where the upper Morrison is predominantly shale.

ORIGIN OF THE KAOLIN

The origin of the white clays of Georgia was discussed by O. Veatch,[5] and essentially the same theory accepted by Fred R. Neumann[6] for the similar clays in South Carolina. Veatch postulates weathering of the Piedmont land surface from Cambrian to Cretaceous time. The deep residual soil thus formed from the igneous rocks was washed away following uplift at the beginning of the Cretaceous and deposited as alluvial fans or as deltas at the mouths of streams. The white clays were accumulated in offshore lakes, sounds, or landlocked arms of the sea, freshened by runoff from the land. Veatch believes the clays were deposited in fresh water because lime or calcareous layers do not occur in the clay beds. Neumann accepts this theory except that he believes the clays to have been laid down in salt water, pointing to the absence of banding in the clays which might be expected in lacustrine deposits. He postulates that the original residual soil was leached of its iron, leaving the white clays which later were carried to the sea, coagulated by the salts in the sea water, and deposited in quiet areas between deltas. The massive character of the lenticular clay beds he ascribes to rapid deposition.

The Morrison formation, according to Baker, Dane, Reeside,[7] and other workers, was deposited by rivers and in lakes on a little-dissected and poorly drained surface, perhaps under semiarid conditions. These authors state that the upper boundary is certainly a plane of marked

[5] "Kaolins of the Dry Branch Region, Georgia," *Econ. Geol.*, Vol. III (1908), pp. 109–17, and "Second Report on the Clay Deposits of Georgia," *Ga. Geol. Surv., Bull. 18* (1909), pp. 97–103.

[6] "Origin of the White Clays of South Carolina," *Econ. Geol.*, Vol. XXII (1927), pp. 374–87.

[7] *Op. cit.*, p. 55.

erosional unconformity though there are differences of opinion as to the location of this boundary where the Morrison, as they interpret it, contains conglomeratic beds in the upper part.

The kaolinitic cementing material in the white horizon near the contact probably was derived by weathering of feldspathic minerals on this surface during the long time between the deposition of the Morrison and Dakota sediments. W. G. Woolnough[8] points out that the nature of the residual surface products of chemical weathering during the final stages of peneplanation offers a criterion for determining the climatic characteristics prevailing during that period. If the bulk of the residue *in situ* be silica, gibbsite, and kaolinite, he believes the climate was rather uniformly moist, in contrast to the alternation of saturation and desiccation which has given the concretionary, amorphous crust developed in parts of Australia.

This reasoning suggests the development of kaolin on the surface of the Morrison sediments from decomposition of the feldspathic materials during a moist period. The few lenses of pure kaolinite might easily have been formed by local concentration of the fine white clay in small shallow lakes on the old surface. These lakes could also account for the thin lenses of limestone which occur near the kaolin and at about the same horizon on the Mesa Alta outcrops. Subsequent deposition of the Dakota began with a re-working of the surface material on the old plain, mixing the kaolin with sands, removing all traces of kaolin in places, and covering a few small lenses of kaolinite without disturbance other than shallow re-working of the uppermost layers.

[8] "Origin of White Clays and Bauxite and Chemical Criteria of Peneplanation," *Econ. Geol.*, Vol. XXIII (1928), pp. 887–94.

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