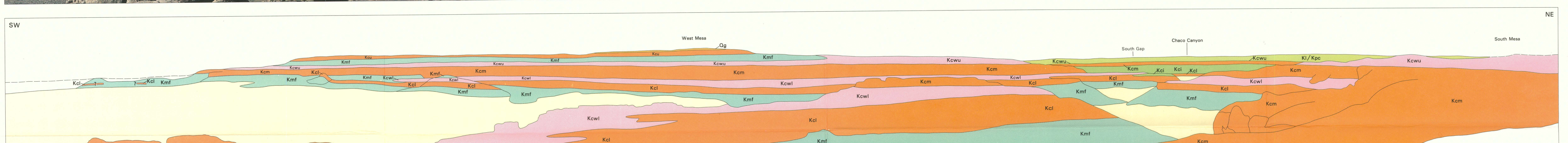
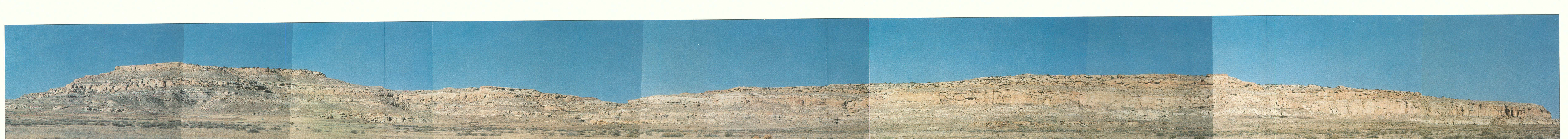
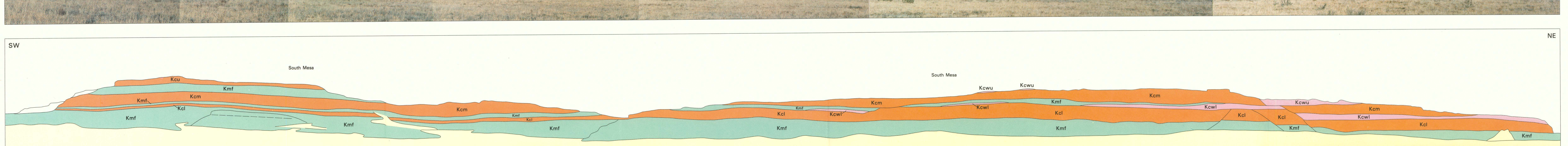
DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

MISCELLANEOUS INVESTIGATIONS SERIES
MAP I-1777

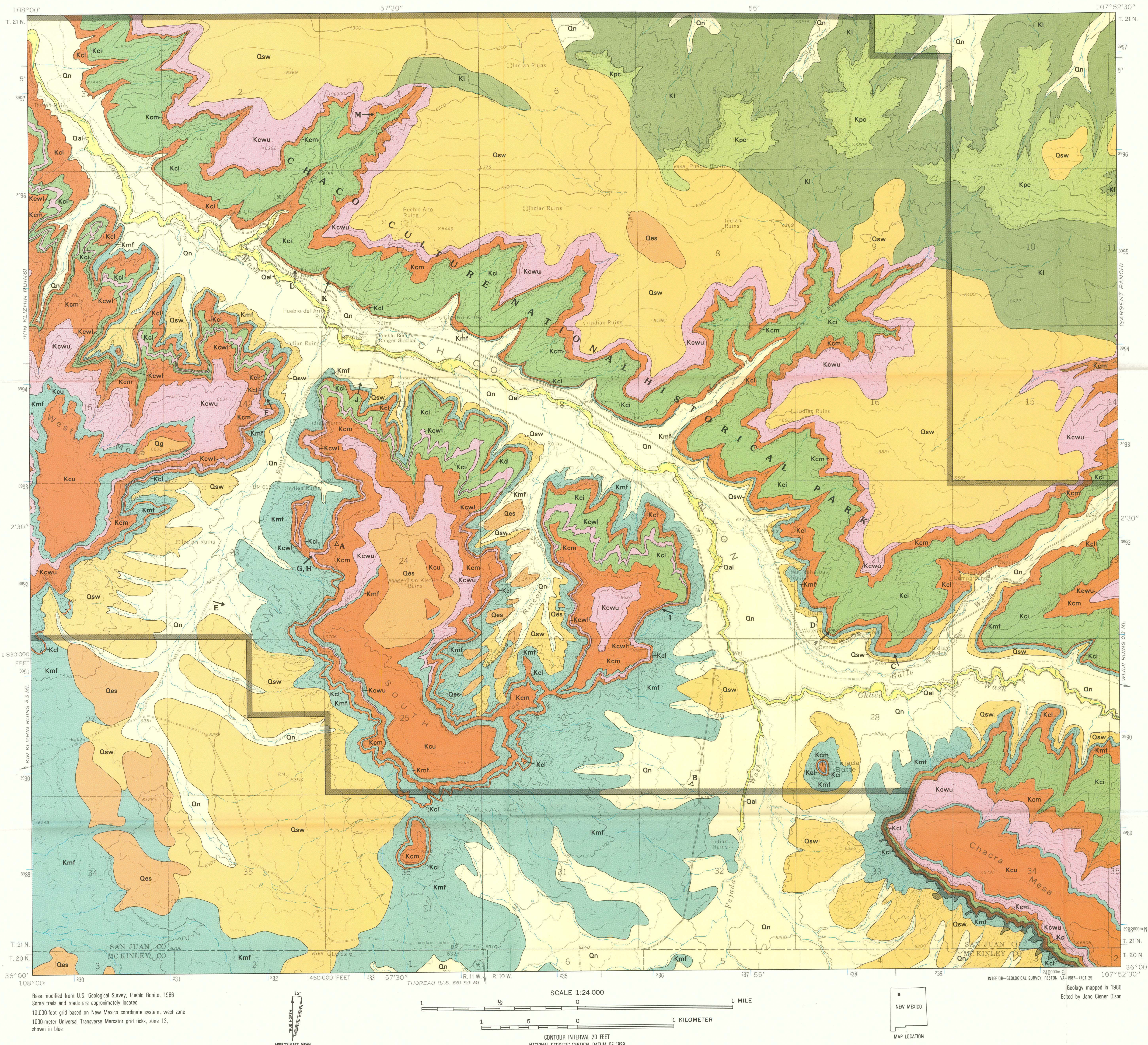


A.—Cliff House Sandstone and Menefee Formation along the east face of West Mesa viewed north of trail to Tsin Kletzin Ruins. The sketch shows rock symbols used on the map. This is one of the best points in the area to see the rocks that show evidence of the shifting coastline during Late Cretaceous time.





B.—Cliff House Sandstone and Menefee Formation along the east face of South Mesa viewed from south entrance of Chaco Culture National Historical Park. The sketch shows rock symbols used on map.



Base modified from U.S. Geological Survey, Pueblo Bonito, 1966
Some trails and roads are approximately located
10,000-foot grid based on New Mexico coordinate system, west zone
1000-meter Universal Transverse Mercator grid ticks, zone 13, shown in blue

APPROXIMATE MEAN DECLINATION, 1987

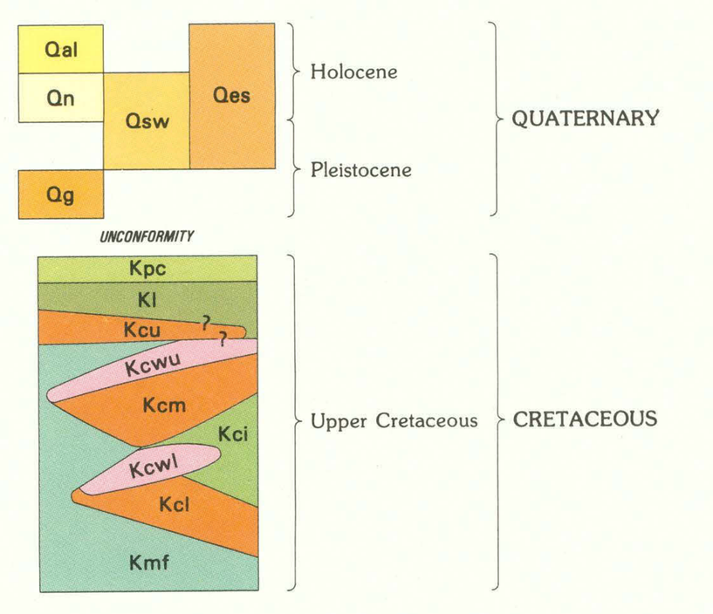
SCALE 1:24 000

CONTOUR INTERVAL 20 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

Geology mapped in 1980
Edited by Jane Ciener Olson

MAP LOCATION

CORRELATION OF MAP UNITS



DESCRIPTION OF MAP UNITS

Qal **Alluvium (Holocene)**—Stream-deposited clay, silt, sand, and gravel. Maximum thickness is approximately 5 ft throughout

Qn **Naha Alluvium of Hack, 1941 (Holocene)**—Laminated and cross-stratified sand and silt filling stream channels. Contains abundant archeological remains of pottery cultures along Chaco Wash. Naha Alluvium overlies Tseigi Alluvium of Hack, 1941, along deep arroyos of Chaco Wash. Thickness ranges from 10 to about 20 ft

Qsw **Sheetwash alluvium (Holocene to upper Pleistocene)**—Poorly consolidated clay, silt, and sand. Thickness is as much as 10 ft

Qes **Eolian sand (Holocene to upper Pleistocene)**—Wind-blown, loose quartz sand in dunes and sand sheets. Thickness is as much as 6 ft

Qg **Gravel (Pleistocene)**—Quartzitic and lithic pebbles and cobbles. Overlies Cliff House Sandstone, at north end of West Mesa. Thickness is about 5 ft

Kpc **Pictured Cliffs Sandstone (Upper Cretaceous)**—Cross-stratified marine sandstone interbedded with a few thin beds of shale. Sandstone contains fossilized burrows (the trace fossil *Ophiomorpha major*) whose outer walls have a knobby appearance that resembles a corn cob. Forms cliffs and ledges. Thickness is about 60 ft

Kl **Lewis Shale (Upper Cretaceous)**—Olive-gray marine shale with thin interbeds of claystone, siltstone, and sandstone, and scattered beds of limestone that contain marine invertebrate fossils. Forms gentle slopes. Thickness is about 100 ft

Cliff House Sandstone (Upper Cretaceous)

Kcu **Upper sandstone**—Thick-bedded, cross-stratified, massive marine sandstone. Includes fossilized burrows (*Ophiomorpha major*). Forms ledges and cliffs. Present only south of Chaco Canyon on West, South, and Chacra Mesas. Thickness on West Mesa increases southwestward from about 30 to more than 60 ft

White to light-gray sandstone—Medium to thick, cross-stratified to evenbedded. Contains few fossilized burrows. Forms ledges and benches

Kcwu **Upper unit**—Overlies middle sandstone (Kcm) and thins southwestward from more than 30 ft on north side of Chaco Canyon to less than 30 ft on south end of West Mesa. On South Mesa, unit changes southwestward into mudstone and carbonaceous shale of Menefee Formation

Kcwl **Lower unit**—Overlies lower sandstone (Kcl) in West and South Mesas and has a maximum thickness of 30 ft. Changes southwestward into mudstone and carbonaceous shale of Menefee Formation. Changes northeastward and southeastward into finer grained sandstone of intermediate unit (Kci)

Kcm **Middle sandstone**—Thick-bedded, cross-stratified, massive marine sandstone. Forms prominent cliffs and ledges. Fossilized burrows (*Ophiomorpha major*) are conspicuous on surfaces of benches above cliffs. Includes highly fossiliferous beds containing clams. Middle sandstone is present throughout the Chaco area and thickens southwestward from about 80 ft on north side of Chaco Canyon to about 130 ft on south end of West Mesa

Kci **Intermediate unit**—Thin- to thick-bedded, lenticular and cross-stratified marine sandstone containing fossilized burrows (*Ophiomorpha major*). Forms gentle slopes and benches. Marine shale, lithologically similar to Lewis Shale, is locally interbedded with sandstone on north side of Chaco Canyon. Light-gray, cross-stratified sandstone similar to Kcwl, but too thin to show on map, is locally present near base of unit. Thickness of unit is about 120 ft

Kcl **Lower sandstone**—Thick-bedded, cross-stratified, massive marine sandstone. Forms prominent cliffs nearly 100 ft high above ruins on north side Chaco Canyon. Contains churned beds produced by burrowing organisms and includes local highly fossiliferous beds containing clams. Fossilized burrows (*Ophiomorpha major*) are very common and are seen in sandstone blocks in the Anasazi ruins at Pueblo Bonito and Chetro Kettle. Lower sandstone thins from nearly 100 ft in Chaco Canyon to slightly more than 10 ft on south end of West Mesa. Wedges out southwestward into mudstone and carbonaceous shale of Menefee Formation

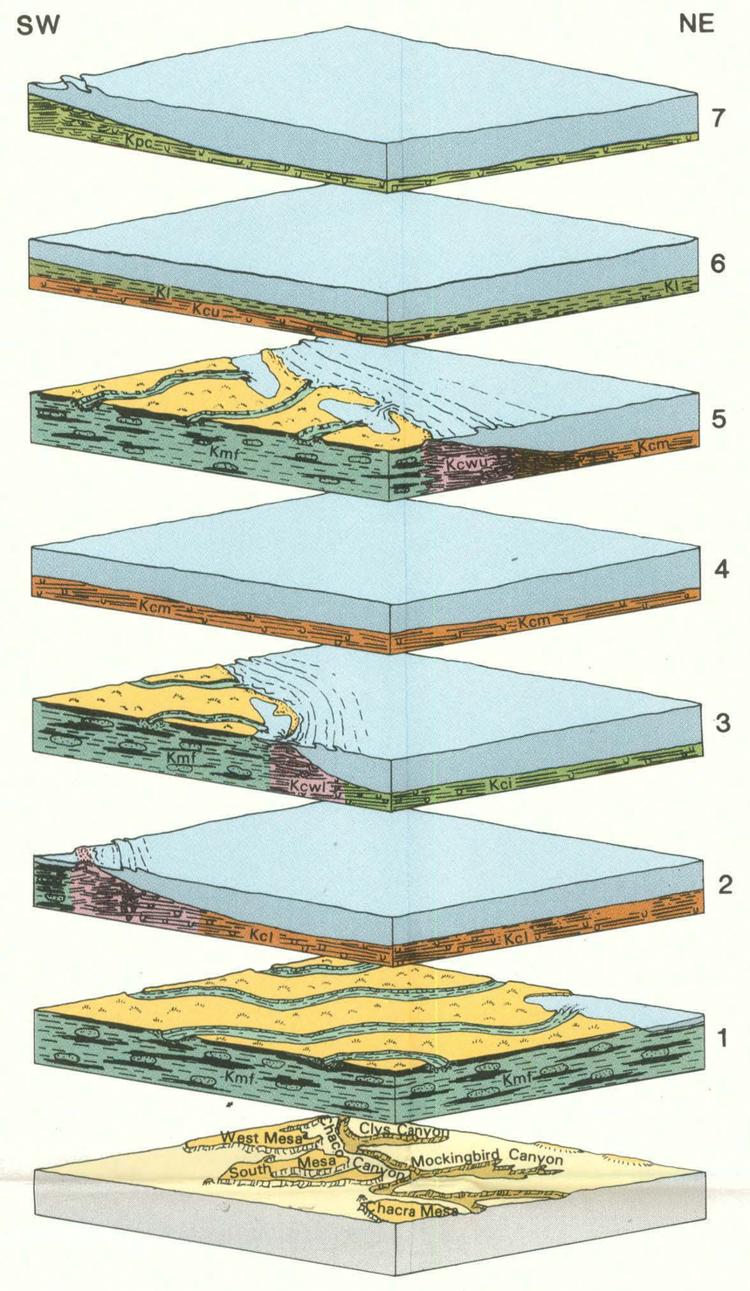
Kmf **Menefee Formation (Upper Cretaceous)**—Mudstone and siltstone interbedded with cross-stratified lenticular sandstone. Contains carbonaceous shale and thin coal beds. Coal is burned in areas on south side of West and South Mesas. Forms steep to gentle slopes. Upper part wedges out between sandstone units of Cliff House. Thickness of main body is over 160 ft; Menefee wedges out between lower and middle sandstones from a maximum thickness of about 100 ft; Menefee wedges out between middle and upper sandstones from a maximum thickness of about 50 ft

Boundary of the Chaco Culture National Historical Park

Contact

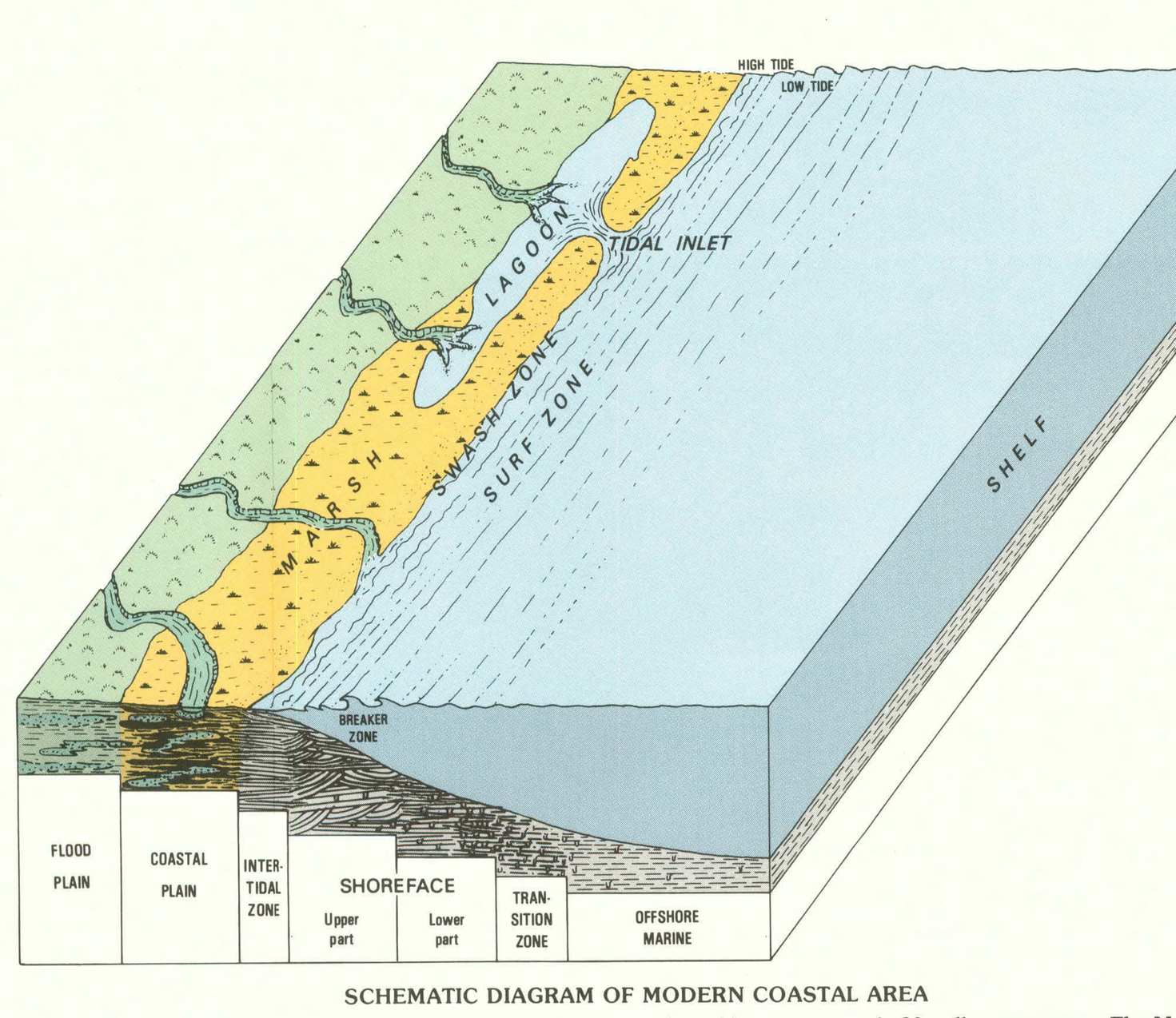
←C Site from which photograph was taken—Symbol shows direction camera faced

◁B Panoramic view—Symbol shows direction camera faced



BLOCK DIAGRAMS OF PALEOGEOGRAPHY

Diagrams show the shifting seas of the Chaco area during deposition of the Menefee Formation, Cliff House Sandstone, Lewis Shale, and Pictured Cliffs Sandstone. For explanation of geologic symbols, see Description of Map Units for geologic map. Coastal-plain deposits of the Menefee Formation (Kmf) (block 1) were buried by marginal marine sediments (lower Cliff House Sandstone, Kcl) deposited in an advancing sea (block 2). The marginal marine sediments (Kcl) accumulated in the lower part of the shoreface at depths which may have been as much as 70 ft below sea level. Sediments (Kci) that accumulated to the northeast during this time, and later were deposited on the lower sandstone, are transitional between the sands of the lower shoreface and silts and shales (Kl) offshore. The shoreline shown in block 2 is located southwest of the boundary of Chaco Culture National Historical Park where the Cliff House Sandstone has been removed by erosion. This shoreline is believed to be close to the position of the shoreline that marked the furthest advance of the sea before it began its retreat to the northeast. Retreat of the sea (block 3) resulted in the building up and out of sediments (Kcwl) from the shoreline by deposition in tidal inlets, in the zone between high and low tide, and in the upper part of the shoreface in water as deep as 20 ft. Coastal-plain deposits of the Menefee Formation (Kmf) accumulated southwest of the shoreline and lower shoreface deposits (Kci) accumulated seaward to the northeast. Renewed advance of the sea (block 4) brought complete inundation of coastal areas and deposition of lower shoreface sediments of the middle sandstone (Kcm) of the Cliff House. The seashore marking the furthest advance of marine waters during this episode would have been several miles southwest of the Park. Seaward, accumulation of sediments (Kci) transitional from those of the lower part of the shoreface to offshore marine would have taken place. Building upward and outward of the shoreline once again took place in response to the retreat of the sea (block 5) with deposition of material (Kcwu) in an inner tidal zone and upper shoreface that were advancing seaward and overiding sediments (Kcm) of the lower part of the shoreface. To the southwest, coastal-plain deposits of the Menefee (Kmf) accumulated. Building upward and outward of the shoreline (block 5) was followed by the final inundation by the Late Cretaceous sea during which time the upper sandstone (unit Kcu) of the Cliff House and the Lewis Shale (Kl) were deposited (block 6). Only a minimal amount of sediment accumulated and (or) was preserved in the lower part of the shoreface southwest of the advancing sea before the upper sandstone was buried by the Lewis Shale. The furthest advance of the sea probably was not to distant southwest of the Park boundary, because the Lewis Shale, in localities where it has not been removed by erosion, is much thinner than in the Park. The Pictured Cliffs Sandstone (Kpc), which overlies the Lewis Shale, represents a seaward advance of the shoreline to the northeast (block 7) and the beginning of the final retreat of the Late Cretaceous sea across northern New Mexico.



SCHEMATIC DIAGRAM OF MODERN COASTAL AREA

Depositional environments believed to be most typical of those of the Chaco area nearly 80 million years ago. The Menefee Formation and Cliff House Sandstone have sedimentary features, shown in the photographs, that are similar to those illustrated in the diagram. These features are used to interpret ancient depositional environments of the Late Cretaceous seaway that once covered much of New Mexico.

EXPLANATION

Flood plain—The surface of relatively smooth land adjacent to a river channel, constructed by the present river in its existing course and covered with water when the river overflows its banks at times of high water. The flood plain is built of alluvium carried by the river during floods and deposited beyond the normal reaches of the river. Flood-plain deposits include lenticular sandstone bodies, representing filled river channels, as well as mudstones and siltstones that are adjacent to, overlie, and underlie the channel deposits. The Menefee Formation (Kmf) within the boundary of Chaco Culture National Historical Park does not have flood-plain deposits; however, outside the Park, rocks of the Menefee older than those shown on the geologic map represent the flood-plain environment.

Coastal plain—A low-lying plain which borders the sea and extends inland to the nearest elevated area such as an alluvial flood plain. Coastal-plain deposits include sands that fill river channels, muds and silts that fill lagoons, and dark carbonaceous mud and peat that accumulate in marshes or swamps. The Menefee Formation (Kmf) in the Chaco area is made up of coastal-plain sediments.

Intertidal zone—The zone between the high-water line (high tide) and low-water line (low tide) of the shoreline and referred to as the foreshore. The intertidal zone includes the swash zone, the sloping part of the beach that is alternately covered and uncovered by the uprush of waves and where longshore movement of water occurs in a zigzag (upslope-downslope) manner. Foreshore deposits are generally composed of light-colored, well-sorted quartzose sandstone, such as Cliff House units Kcwu and Kcwl, in beds that are nearly parallel and initially dip seaward at very low angles (2 to 6 degrees). Inland, the foreshore adjoins an area generally above the high-water level referred to as the backshore where sand dunes may form. The coastal plain can be nearly adjacent to the foreshore in cases where the backshore is poorly developed or nearly nonexistent, which may be the case in the Cliff House Sandstone of the Chaco area.

Shoreface—The nearshore area that is always submerged and is situated between low-water level (low tide) and the last point seaward where the action of waves effectively moves sediments of the sea bottom. The upper part of the shoreface in the Chaco area has cross-stratified and even-bedded, light-colored sandstone (Kcwu and Kcwl) that is coarser grained than the sandstone of the lower part and is indicative of deposition within the breaker and surf zones. The lower part encompasses the area from just seaward of the breakers to the base of the shoreface and is made up of quartzose sandstone that is cross stratified to horizontally parallel laminated. Compared to the intertidal zone (foreshore), the shoreface is barren of fossil shells except in places where violent storms have produced waves large enough to move shells from the beaches down the slope of the shoreface. Fossil burrows (trace fossils) are more common in the lower part than in the upper part of the shoreface and during quiescent periods between storms are formed by burrowing organisms in the sediment of the sea bottom. The rocks of this lower shoreface environment, as typified by the thick-bedded massive units (Kcu, Kcm, Kcl) of the Cliff House Sandstone, are highly burrowed sandstones that alternate with cross-stratified to horizontal parallel-laminated sandstone.

Transition zone—The depositional environment transitional between shoreface and offshore marine in which sand, silt, and mud are deposited and only burrowing organisms such as shrimp abide in the bottom sediment of the sea floor. Sand is supplied to the transition zone from the shoreface generally during major storms. Thin beds of sandstone alternating with thin beds of siltstone or mudstone are characteristic of this zone. In the Chaco area, a transition zone has been identified at the base of the Pictured Cliffs Sandstone (Kpc) where it grades downward into the Lewis Shale. The transition zone may be represented, in part, by beds of the intermediate unit (Kci) of the Cliff House Sandstone.

Offshore marine—Area below the maximum effect of waves and marked by a more gentle slope to a flattening of the sea bottom and by the accumulation of sediments which are typically silt and mud and, in part, limy. Sand is supplied only under rare and extraordinary conditions. Marine fossils of organisms more common to the open sea and the shelf area of the sea floor are present in the rocks. The Lewis Shale (Kl) represents the offshore marine environment.

Tidal inlet—A natural inlet, maintained by tidal currents, through which marine water from the open sea flows alternately landward with the rising tide and seaward with the falling tide. Deltas may form at the mouth of the inlet on both the seaward and lagooon sides of a barrier beach, barrier island, or barrier to a bay (baymouth bar) by the changing tidal currents that sweep sand in and out of the inlet. High-angle cross-stratified sandstones of the Cliff House (Kcwu and Kcwl) may be examples of this environment.

DISCUSSION

Rocks exposed at the surface in the Chaco area provide a record of a small part of earth history that started about 80 million years ago. These rocks represent a geographical setting that was completely different from what we see here today. The rocks, 75–80 million years old, record an interval of geologic time in the Late Cretaceous when Chaco Canyon and vicinity were the site of a shifting coastline reflecting the spread and retreat of an ancient sea that covered the Western Interior of the United States.

The oldest rocks exposed are the uppermost part of the Menefee Formation, predominantly mudstone containing carbonaceous shales and thin coal beds interspersed with sandstone beds. Within Chaco Culture National Historical Park, the Menefee forms steep slopes that underlie mesas capped by the Cliff House Sandstone. South of the Park, the Menefee underlies broad areas of low relief and isolated buttes and mesas. Fajada Butte, located south of the Visitors Center and perhaps the most impressive landmark in the Park, was formerly part of Chacra Mesa. In recent geologic time (Holocene) Fajada Butte has become detached from the mesa through erosion and is now but a remnant of Menefee overlain by a protective cap of Cliff House Sandstone.

Interbedded, wedge-shaped layers of the Cliff House Sandstone and Menefee Formation can be seen in the cliffs of West and South Mesas. Some of the rocks of the Menefee, which were originally laid down as sediments near the seashore, thin and disappear to the northeast. The marginal-marine sandstones of the Cliff House, whose imposing cliffs rise above the prehistoric ruins on the floor of the canyon, thin and disappear to the southwest. An intermediate unit (Kci) is shown between the lower and middle cliff-forming sandstones of the Cliff House. Characterized by thin- to thick-bedded sandstones, the intermediate unit forms benches and gentle slopes and is locally interbedded with shales similar to those of the Lewis Shale.

The Lewis Shale, a rock unit laid down in the open sea, lies above the Cliff House Sandstone northeast of Chaco Canyon, but, over a large area this shale is covered by loose surficial deposits. Where not covered by surficial material, the Lewis Shale is overlain by the Pictured Cliffs Sandstone, rock similar to the Cliff House.

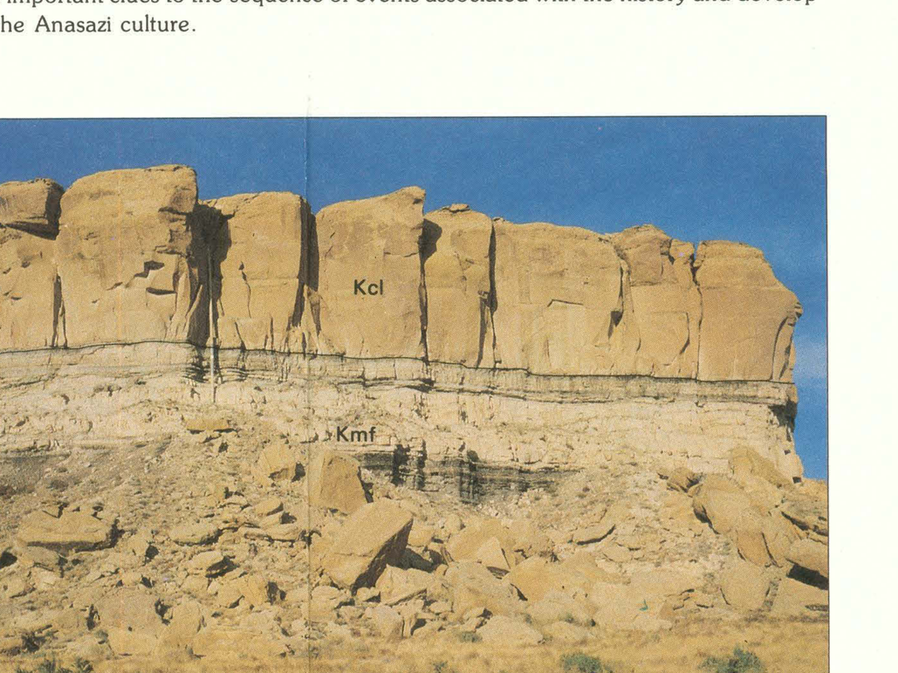
Beds that thin out progressively until they end, such as those in the main part of the Menefee Formation and the white sandstone (Kcwu and Kcwl) in sec. 30, T. 21 N., R. 10 W., on the southeast face of South Mesa, are actual changes in rock type. Apparent thinning-out and termination of units on the map, such as Kcl to the northeast in the same section and in sec. 13, T. 21 N., R. 11 W., south of Chaco Wash, as well as those in the rock units on the northeast faces of the mesas above Chaco Canyon, are caused by cliffs and overhangs that make it difficult to portray these features easliy on a map of this scale.

The unconsolidated to poorly consolidated Quaternary deposits, which partially mask the older rocks, reflect periods of sedimentation by water and wind from as long ago as 2 million years down to the present day. Geologic processes still actively sculpture the land surface into the canyons and high mesas we see today. The gravel cap on West Mesa is the oldest Quarternary deposit and is probably of Pleistocene age (the epoch associated with continental glaciation in North America). The gravel covers an old erosion surface related to changes in the downcutting of the Chaco and San Juan Rivers. In order of decreasing age the other surficial materials include wind-blown sand; poorly consolidated clay, silt, and sand called sheetwash alluvium; laminated and cross-stratified sand and silt, identified as Naha Alluvium; and present day stream-deposited alluvium of Chaco Wash. Archeologists believe the Naha Alluvium is the most notable surficial deposit because it contains buried artifacts, which are important clues to the sequence of events associated with the history and development of the Anasazi culture.

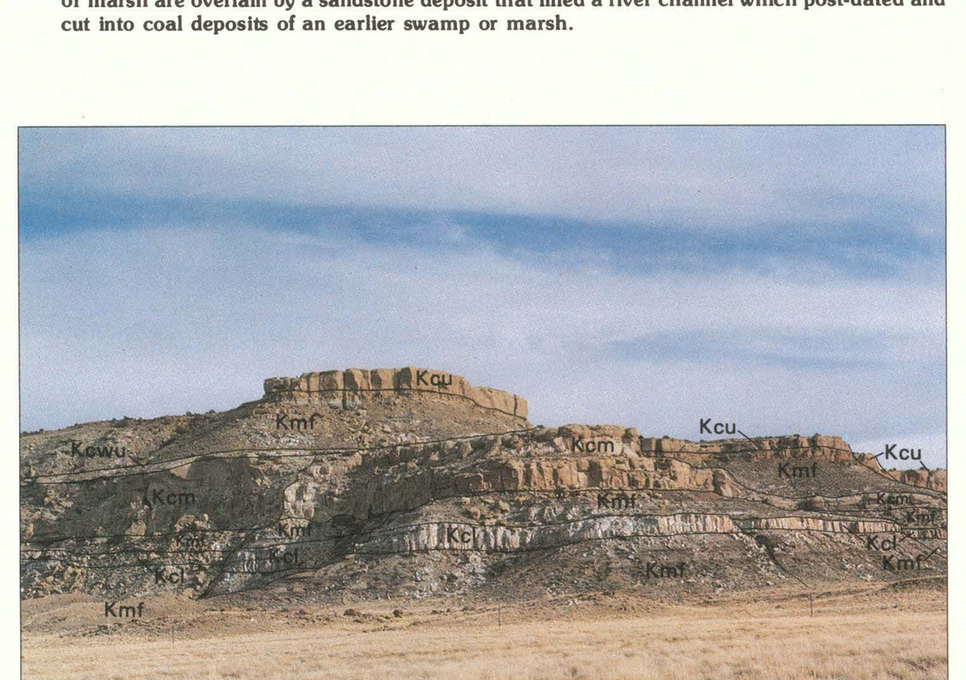
REFERENCES

Balsley, J. K., 1980, Cretaceous wave-dominated delta systems—Book Cliffs, east-central Utah: Denver, Colo., Amoco Production Company, 163 p.
Bates, R. L., and Jackson, J. A., eds., 1980, Glossary of geology (2d ed.): Falls Church, Va, American Geological Institute, 749 p.
Hack, J. T., 1941, Dunes of the western Navajo Country: Geophysical Review, v. 31, no. 2, p. 240-263.
Reinech, H. E., and Singh, I. B., 1980, Depositional sedimentary environments (2d ed.): New York, Springer-Verlag, 549 p.
Scott, G. R., O'Sullivan, R. B., and Weide, D. L., 1984, Geologic map of the Chaco Cultural National Historical Park, northwestern New Mexico, *with a chapter on* Archeology by W. B. Gillespie: U.S. Geological Survey Miscellaneous Investigations Series I-1571, scale 1:50,000.
Weide, D. L., Schneider, G. B., Mytton, J. W., and Scott, G. R., 1979, Geologic map of the Pueblo Bonito quadrangle, San Juan County, New Mexico: U.S. Geological Survey Miscellaneous Field Studies Map MF-1119, scale, 1:24,000.

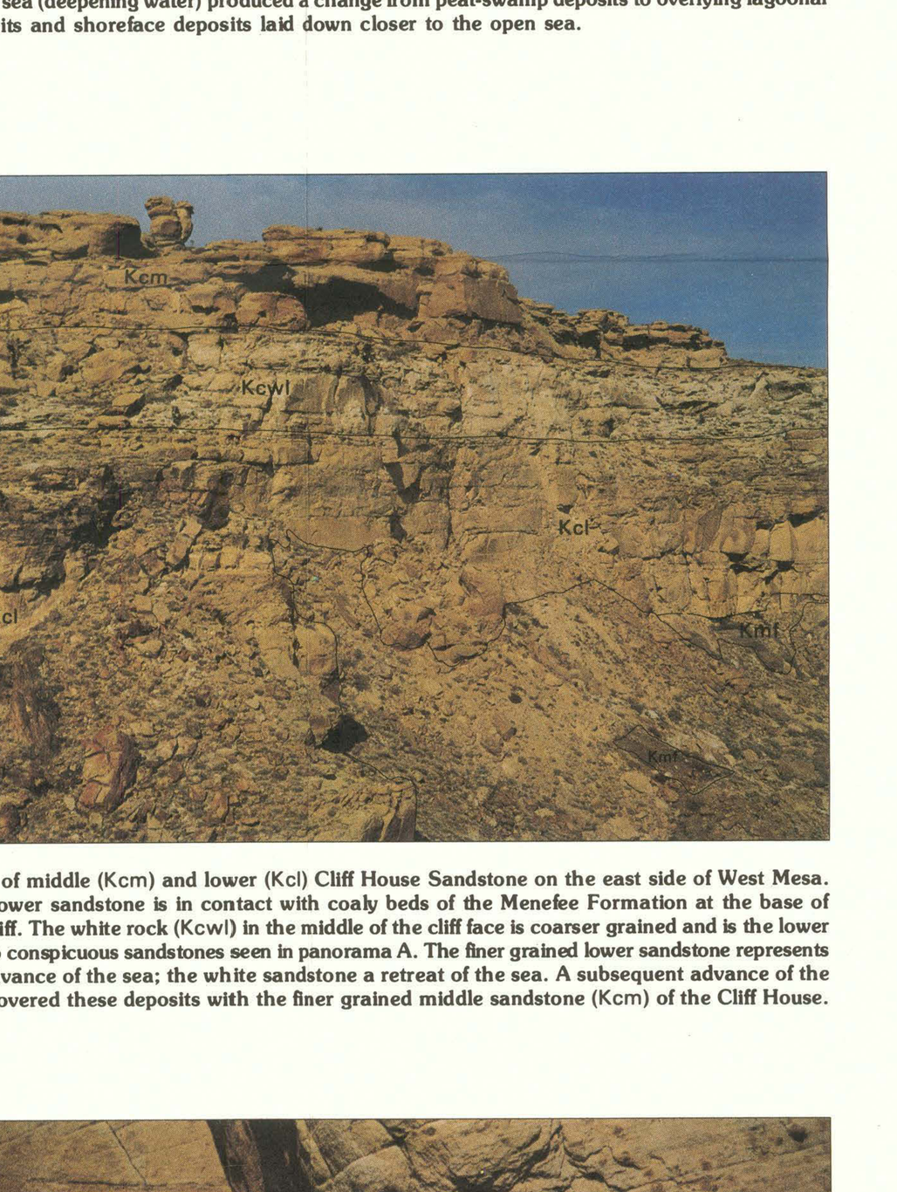
C.—Coastal plain deposits of the Menefee Formation viewed from the road between the visitor's center and the campground. Mudstone, carbonaceous shale, and coal representative of a swamp or marsh are overlain by a sandstone deposit that filled a river channel which post-dated and cut into coal deposits of an earlier swamp or marsh.



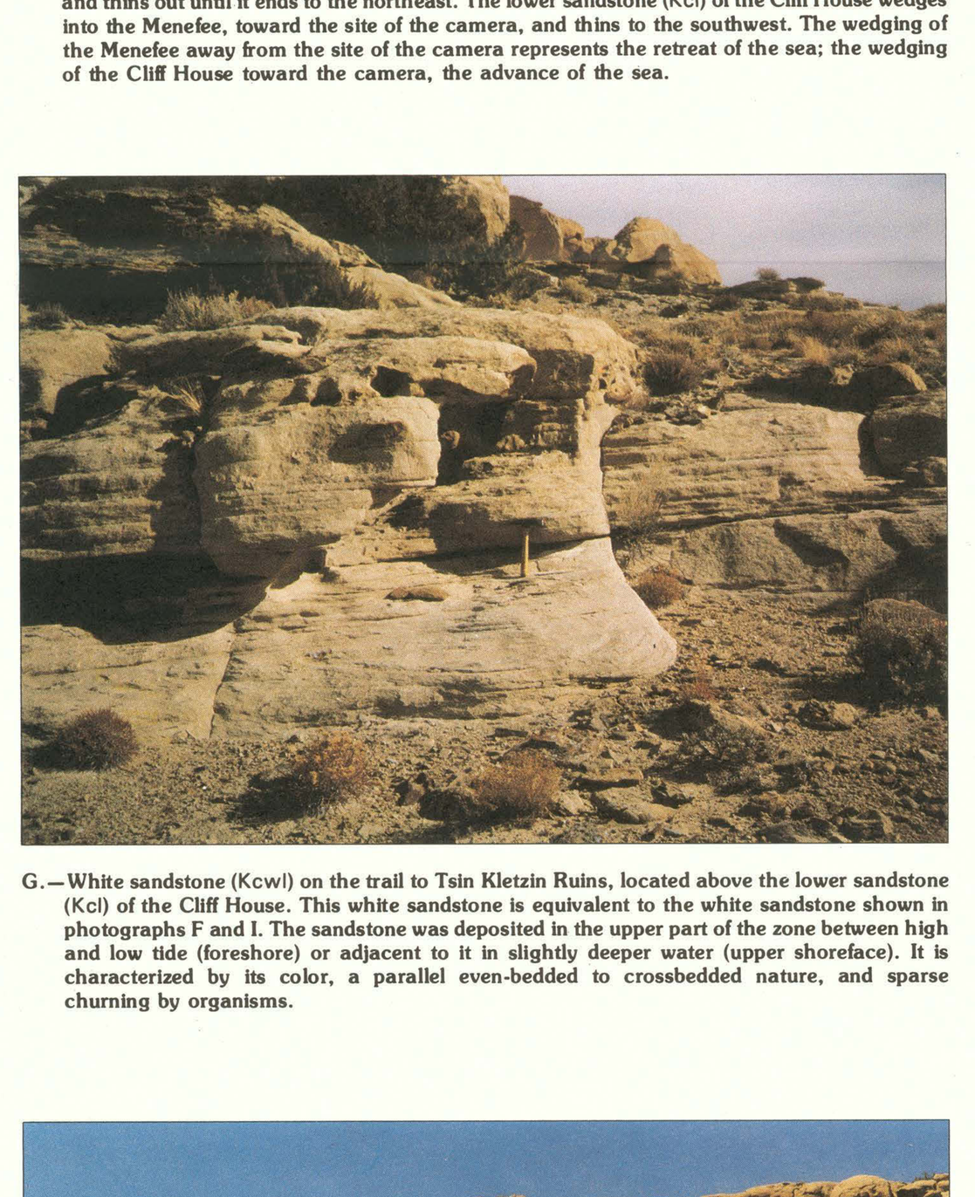
D.—Contact between the lower sandstone (Kcl) of the Cliff House Sandstone and the main body of the Menefee Formation, above Visitor's Center to north. A fairly rapid landward movement of the sea (deepening water) produced a change from peat-swamp deposits to overlying lagoonal deposits and shoreface deposits laid down closer to the open sea.



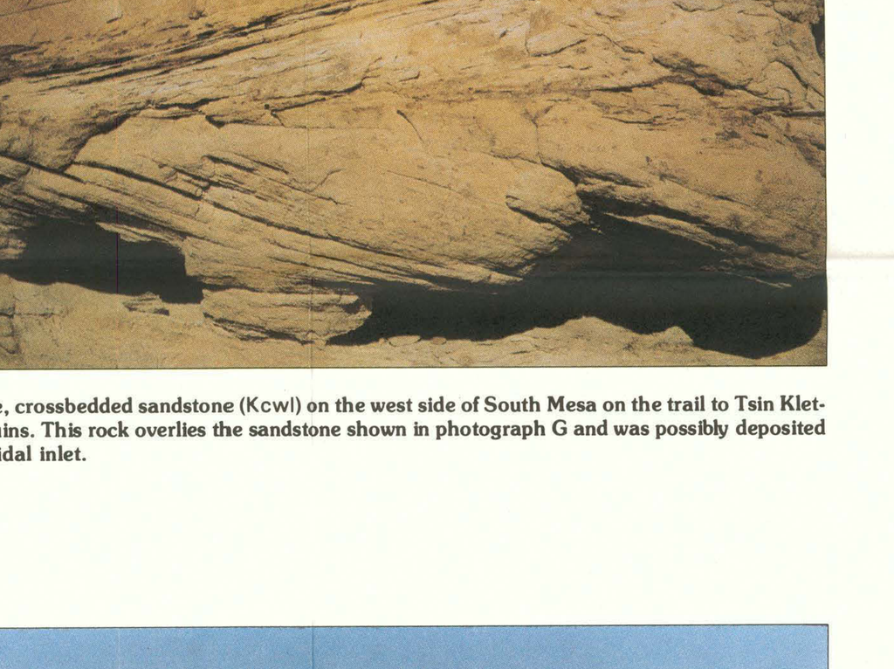
E.—The Cliff House Sandstone on the southwest edge of South Mesa. The Menefee wedges into the upper and middle sandstones (Kcu and Kcm) of the Cliff House, away from the camera, and thins out until it ends to the northeast. The lower sandstone (Kcl) of the Cliff House wedges into the Menefee, toward the site of the camera, and thins to the southwest. The wedging of the Menefee away from the site of the camera represents the retreat of the sea; the wedging of the Cliff House toward the camera, the advance of the sea.



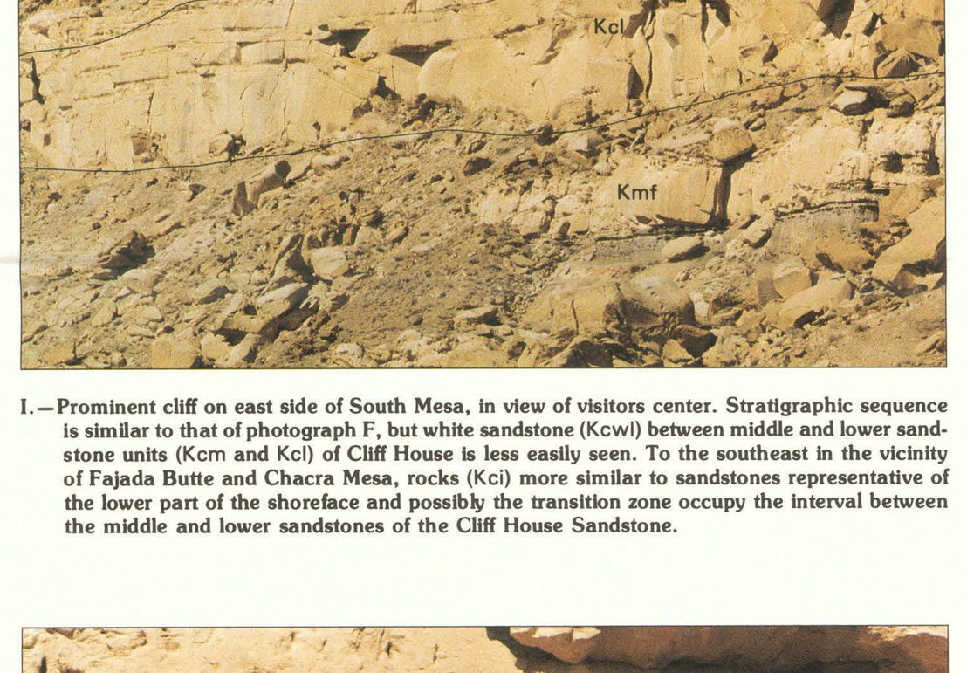
F.—Cliffs of middle (Kcm) and lower (Kcl) Cliff House Sandstone on the east side of West Mesa. The lower sandstone is in contact with coaly beds of the Menefee Formation at the base of the cliff. The white rock (Kcwl) in the middle of the cliff face is coarser grained and is the lower of two conspicuous sandstones seen in panorama A. The finer grained lower sandstone represents an advance of the sea; the white sandstone a retreat of the sea. A subsequent advance of the sea covered these deposits with the finer grained middle sandstone (Kcm) of the Cliff House.



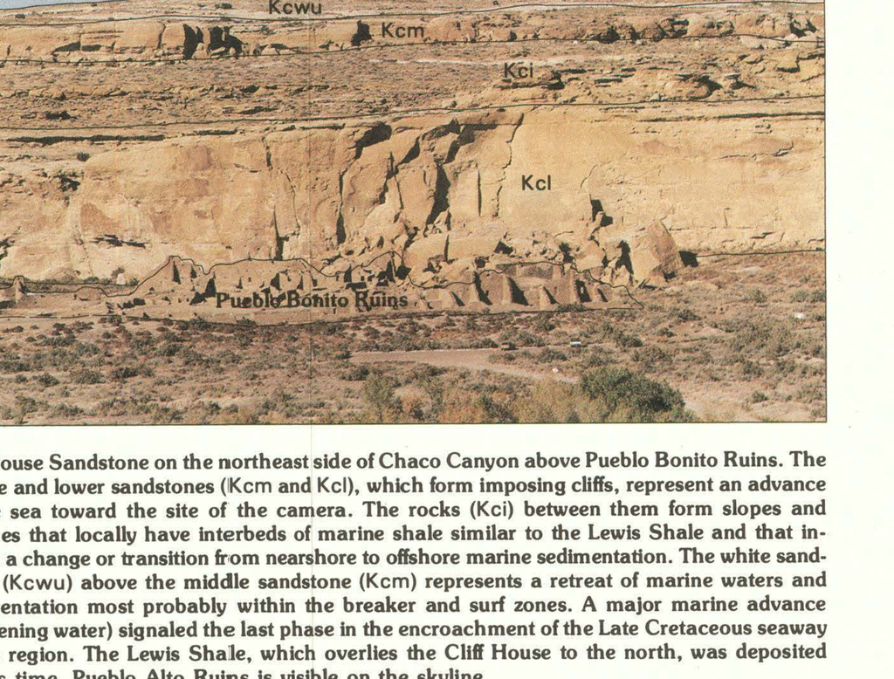
G.—White sandstone (Kcwl) on the trail to Tsin Kletzin Ruins, located above the lower sandstone (Kcl) of the Cliff House. This white sandstone is equivalent to the white sandstone shown in photographs F and I. The sandstone was deposited in the upper part of the zone between high and low tide (foreshore) or adjacent to it in slightly deeper water (upper shoreface). It is characterized by its color, a parallel even-bedded to crossbedded nature, and sparse churning by organisms.



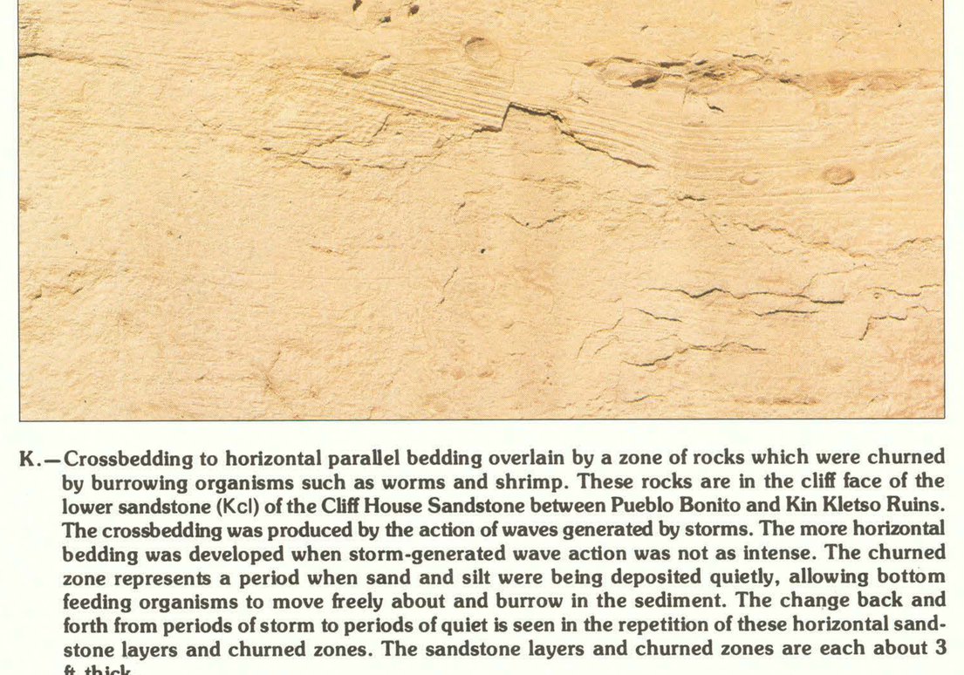
H.—White, crossbedded sandstone (Kcwl) on the west side of South Mesa on the trail to Tsin Kletzin Ruins. This rock overlies the sandstone shown in photograph G and was possibly deposited in a tidal inlet.



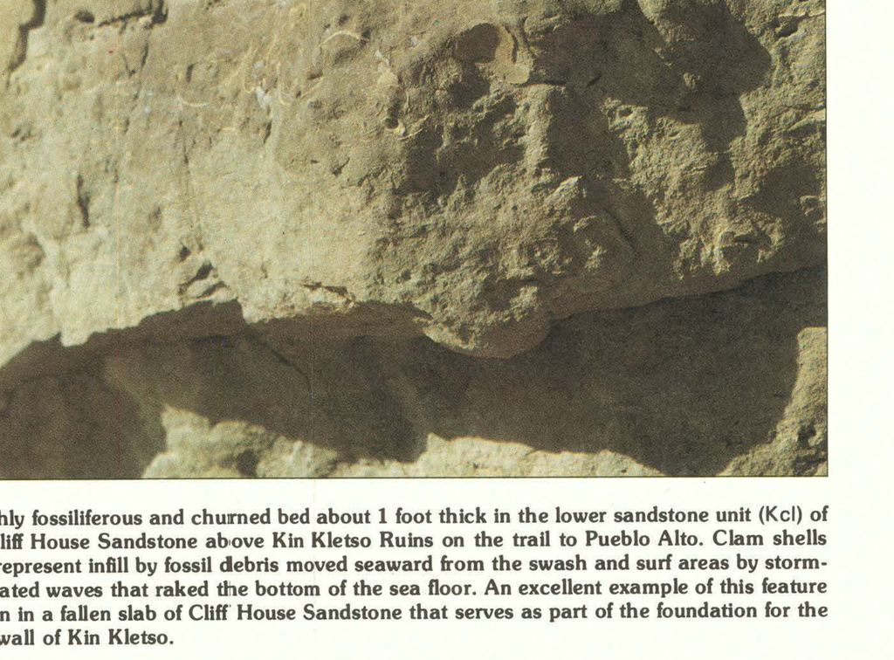
I.—Prominent cliff on east side of South Mesa, in view of visitors center. Stratigraphic sequence is similar to that of photograph F, but white sandstone (Kcwl) between middle and lower sandstone units (Kcm and Kcl) of Cliff House is less easily seen. To the southeast in the vicinity of Fajada Butte and Chacra Mesa, rocks (Kci) more similar to sandstones representative of the lower part of the shoreface and possibly the transition zone occupy the interval between the middle and lower sandstones of the Cliff House Sandstone.



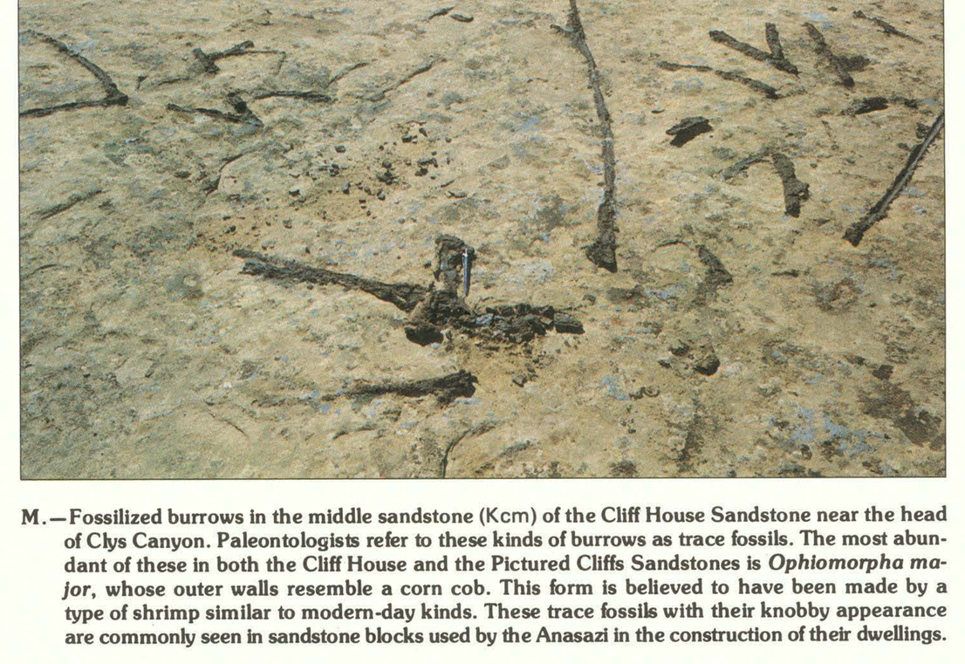
J.—Cliff House Sandstone on the northeast side of Chaco Canyon above Pueblo Bonito Ruins. The middle and lower sandstones (Kcm and Kcl), which form imposing cliffs, represent an advance of the sea toward the site of the camera. The rocks (Kci) between them form slopes and benches that locally have interbeds of marine shale similar to the Lewis Shale and that indicate a change or transition from nearshore to offshore marine sedimentation. The white sandstone (Kcwu) above the middle sandstone (Kcm) represents a retreat of marine waters and sedimentation most probably within the breaker and surf zones. A major marine advance (deepening water) signaled the last phase in the encroachment of the Late Cretaceous seaway in the region. The Lewis Shale, which overlies the Cliff House to the north, was deposited at this time. Pueblo Alto Ruins is visible on the skyline.



K.—Crossbedding to horizontal parallel bedding overlain by a zone of rocks which were churned by burrowing organisms such as worms and shrimp. These rocks are in the cliff face of the lower sandstone (Kcl) of the Cliff House Sandstone between Pueblo Bonito and Kin Kletso Ruins. The crossbedding was produced by the action of waves generated by storms. The more horizontal bedding was developed when storm-generated wave action was not as intense. The churned zone represents a period when sand and silt were being deposited quietly, allowing bottom feeding organisms to move freely about and burrow in the sediment. The change back and forth from periods of storm to periods of quiet is seen in the repetition of these horizontal sandstone layers and churned zones. The sandstone layers and churned zones are each about 3 ft thick.



L.—A highly fossiliferous and churned bed about 1 foot thick in the lower sandstone unit (Kcl) of the Cliff House Sandstone above Kin Kletso Ruins on the trail to Pueblo Alto. Clam shells may represent infill by fossil debris moved seaward from the swash and surf areas by storm-generated waves that raked the bottom of the sea floor. An excellent example of this feature is seen in a fallen slab of Cliff House Sandstone that serves as part of the foundation for the west wall of Kin Kletso.



M.—Fossilized burrows in the middle sandstone (Kcm) of the Cliff House Sandstone near the head of Clys Canyon. Paleontologists refer to these kinds of burrows as trace fossils. The most abundant of these in both the Cliff House and the Pictured Cliffs Sandstones is *Ophiomorpha major*, whose outer walls resemble a corn cob. This form is believed to have been made by a type of shrimp similar to modern-day kinds. These trace fossils with their knobby appearance are commonly seen in sandstone blocks used by the Anasazi in the construction of their dwellings.

SELECTED GEOLOGIC FEATURES OF THE CHACO CANYON AREA. LOCATIONS SHOWN BY LETTERS ON THE MAP

INTERPRETIVE GEOLOGY OF THE CHACO AREA, NORTHWESTERN NEW MEXICO

By
James W. Mytton and Gary B. Schneider

1987

INTERIOR—GEOLOGICAL SURVEY, RESTON, VA—1987—77701 29

For sale by U.S. Geological Survey, Map Distribution, Box 25286, Federal Center, Denver, CO 80225