Geology and coal resources of Pasture Canyon quadrangle, Catron County, New Mexico

JoAnne Cima·Osburn

Field Coal Geologist

New Mexico Bureau of Mines and Mineral Resources

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1 plate

Introduction

Purpose and scope

The details of the depositional environments and the lithologies represented by the Upper Cretaceous Crevasse Canyon Formation and the general geology of the Datil Mountains coal field have not been previously examined. At present coal is being economically mined from the Crevasse Canyon Formation in the San Juan Basin, it follows that the formation should be evaluated for coal resources outside currently-mined basins. This map is the seventh in a series of 7 1/2' quadrangles to be mapped at 1:24,ØØØ in the Datil Mountains coal field. The purpose of this work has been to provide basic geologic data for those interested in further coal resource evaluation of the Datil Mountains area.

Location and accessibility

Pasture Canyon quadrangle is located in the northeastern corner of Catron County, about 25 mi due north of Datil, New Mexico (fig. 1). The study area is located in the south-central part of the Datil Mountains coal field. Access to the study area is limited; the closest paved road is US-6Ø, about 25 miles to the south. U.S. Forest road 6 and its northern continuation are usually maintained. The remaining roads in the area are fair to poor quality; four-wheel drive vehicles are in order.

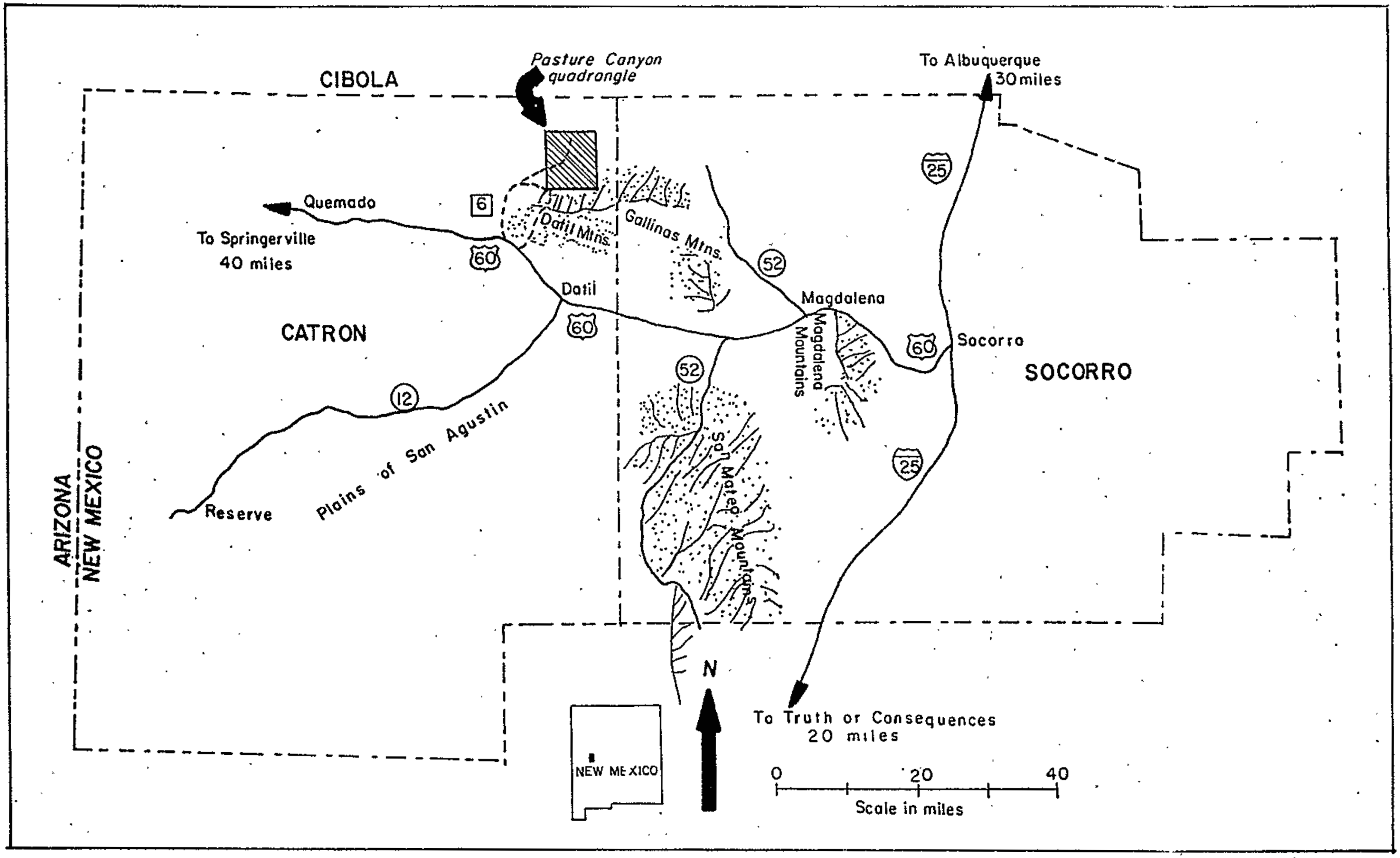


Figure 1. Location map showing Pasture Canyon quadrangle in relation to roads and mountain ranges in west central New Mexico.

Surface and mineral ownership

Surface ownership in Pasture Canyon quadrangle is divided among Federal (49%) State of New Mexico (7%), and private individuals (44%) (fig. 2). The Federal government holds 30% as National Forest Service land and 19% as public domain land. Private owners, include both large ranch owners and many small-acreage homesteaders.

Mineral ownership in Pasture Canyon quadrangle is divided among private (56%), federal (37%), and State of New Mexico (7%) (fig. 3). The Atchison, Topeka, and Santa Fe Railroad holds 48% of all private mineral rights or 27% of the total mineral rights in Pasture Canyon quadrangle. The United States government owns 37% of all the minerals rights concentrated in the southern half of the quadrangle which is National Forest land. Interestingly, 50% of the National Forest land was reconveyed to the federal government without mineral rights during the late 1960's.

Physiography

Pasture Canyon quadrangle is situated in what has been called a transition zone between the Datil-Mogollon subprovince of the Basin and Range Province and the Acoma-Zuni section of the Colorado Plateau (Hawley and Love, 1981). The landscape is dominated by mesas and valleys developed on a southwestward-dipping homocline. The homocline is largely unfaulted and fits the style of the Colorado Plateau better than the more structurally complex style of the Basin and Range Province. Bell Mountain, a Tertiary volcanic neck in the northeastern corner of

Figure 2.

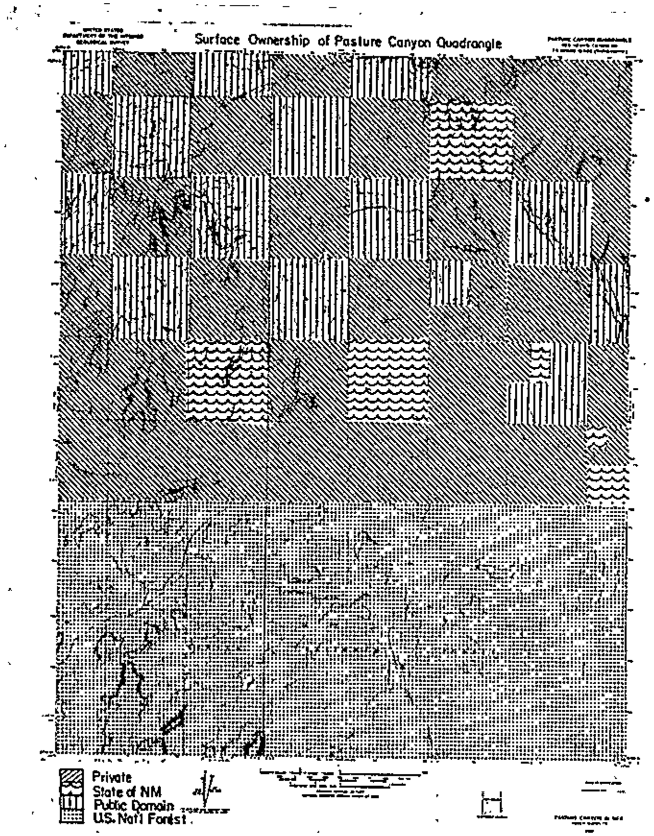
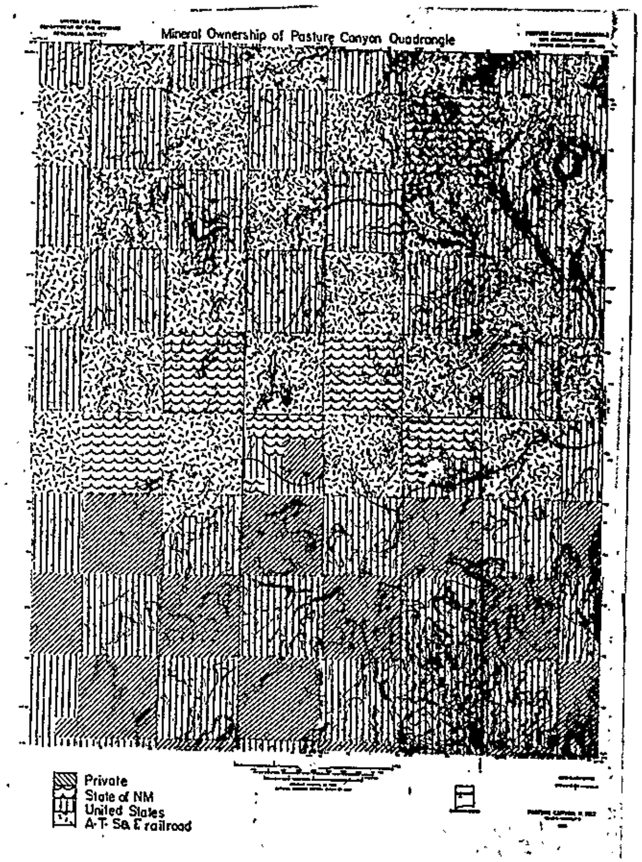


Figure 3.



the quadrangle, is a prominent landmark rising 231 m above average elevation on the quadrangle.

A broad, sandy, intermittent stream, Alamocita Creek, flows east through the center of the quadrangle across the area. Three tributaries of Alamocita Creek trend northward and flow only during the most violent summer storms.

Previous work

The rocks exposed in Pasture Canyon quadrangle have been the subject of reconnaissance studies since the early 1900's. Winchester (1921) visited the area in 1913, plotted many coal outcrops, and identified the major structural features in the area. He erroneously assigned the Bell Mountain Sandstone to a stratigraphic position above the Gallup Sandstone; later work (Dane and others, 1957) showed that Winchester had overlooked a major fault and that the Bell Mountain Sandstone and the Gallup Sandstone are the same unit. Pike (1947) attempted to correlate the Upper Cretaceous units in the Datil Mountains with stratigraphically higher units in the San Juan Basin. Willard and Givens (1958) prepared a reconnaissance map that separated the rocks in Pasture Canyon quadrangle into Mesaverde Group rocks and Mancos Shale units. Foster (1964) and Wengerd (1959) discussed the petroleum possibilities in the area. Frost and others (1979) drilled a coal test hole in Pasture Canyon quadrangle as part of a coal reconnaissance study in the Datil Mountains.

Acknowledgments

I would like to thank the people that live in Pasture Canyon quadrangle who gave me access to their property and extended their warm hospitality to me during the field season. These people include: Chuck and Sharon Draper, Dennis and Bonnie Henslee, Daniel and Karen Howell, and Mike and Delray Kelly.

Sante Fe Mining, Inc. provided unreleased geophysical logs for study and correlation purposes. Edwin Landis and William Mapel of the U.S. Geological Survey, Robert Gray of Santa Fe Mining, Inc., and Orin Anderson of the New Mexico Bureau of Mines and Mineral Resources reviewed and greatly improved and simplified the manuscript. Finally, Marla Adkins-Heljeson edited the manuscript and Nanette Dynan typed and deciphered for the author.

Structure

The overall structure in Pasture Canyon quadrangle is a homocline. The exposed rocks dip gently to the southwest at 3-5o and, except in two places, seem unfaulted. Because the sandstones are discontinuous and the mudstones easily eroded and poorly exposed, faults could be easily obscured.

A northwest-trending normal fault cuts the homocline in the northeastern part of the study area. Displacement is down to the east approximately 60 m. This fault appears to be the westernmost fault in a zone of 20 similar, subparallel faults described by Robinson (1981) on D Cross Mountain quadrangle, just to the east of Pasture Canyon. This structural feature has been called the Cibola anticline by Foster (1964) based on photographic interpretation, but field evidence of slickensides, breccias, and calcite veining along the fault trace indicates faulting.

The Red Lake fault, a major northeast-trending feature in the Datil Mountains, crosses the extreme southeast corner of the study area. Displacement on this fault is generally over 370 m (Robinson, 1981).

Stratigraphy

Rocks exposed in Pasture Canyon quadrangle range from Late Cretaceous to Quaternary in age (fig. 4). Cretaceous units exposed include: D-Cross Tongue of the Mancos Shale, Gallup Sandstone, and Crevasse Canyon Formation. Tertiary rocks mapped include: mafic dikes, intrusive plug, and the Spears Formation. Quaternary units mapped include valley alluvium, sand and gravel in active channels, piedmont slope deposits, and landslide debris.

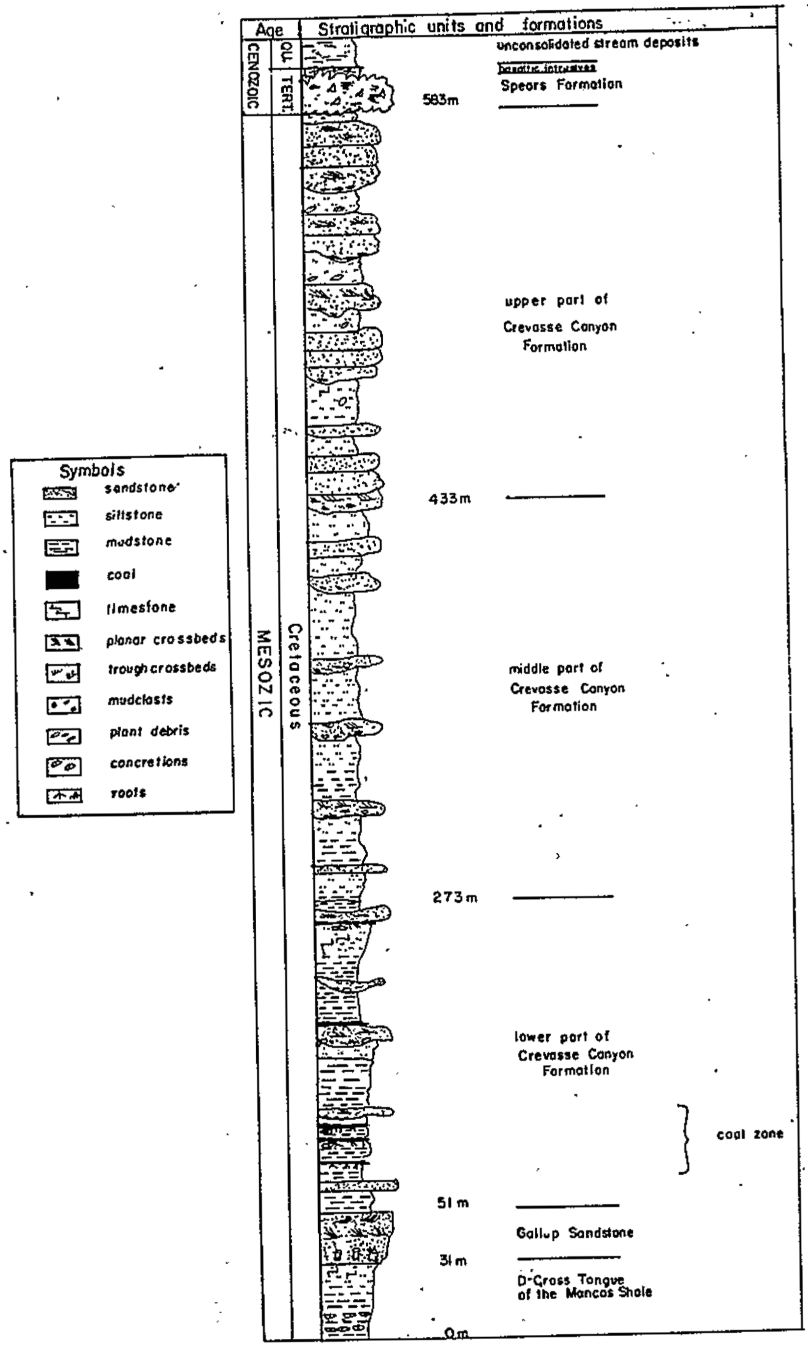
Cretaceous System

D-Cross Tongue of the Mancos Shale

The D-Cross Tongue crops out in the northeastern part of the quadrangle. The stratotype of the D-Cross is about 4 mi east of Pasture Canyon. At the stratotype the unit is 53 m (173 ft) thick (Dane and others, 1957); only the upper 31 m (100 ft) of the D-Cross is exposed in Pasture Canyon quadrangle. The rock is a medium-gray, bioturbated, fossiliferous, locally calcareous shale.

Up to five concretionary zones have been reported in the D-

Figure 4. Stratigraphic units cropping out in Pasture Canyon quadrangle.



Cross (Hook and Cobban, 1979; Robinson, 1981). Two concretionary zones are exposed in the study area. The concretions vary greatly in size, shape, and character, ranging from 10 to 30 cm in diameter, subsequent to elongate shape, and are solid to septarian in character. Fossil ammonites commonly form the core of the concretions and the shale is typically more fossiliferous near concretion zones. Fossils collected from the D-Cross in Pasture Canyon quadrangle include *Prionocyclus novimexicanus*, *Prionocyclus quadratus*, *Inoceramus perplexus*, *Lopha sannionis*, and abundant oyster coquina.

Gallup Sandstone

The Gallup Sandstone is well exposed in the northeastern part of the study area. The Gallup is a regressive coastal barrier unit consisting of 12-20 m (40-65 ft) of upper very fine grained to upper fine-grained, coarsening upward, subarkose; this sequence documents a gradual change from lower to upper shoreface sedimentation.

The contact of the Gallup with the underlying D-Cross Tongue of the Mancos Shale is gradational and consists of a coarsening-upward sequence from siltstones to lower fine-grained sandstones. Grain size for all sandstones was estimated using a comparative chart (American Stratigraphic, undated). The contact between the D-Cross and the Gallup is placed where sandstones become dominant over siltstones. In contrast, the Gallup-Crevasse Canyon Formation contact is sharp and represents the change between a beach environment characterized by fine-grained sandstones and a paludal environment, dominated by mudstones.

The lower part of the Gallup consists of cliffy, light-yellowish-gray sandstone alternating between finely laminated beds, and massive, bioturbated burrow-mottled beds. Small vertical burrows, 5 mm in diameter and 3 cm long, are infrequently present in the massive layers. Elongate sole marks up to 2 m long and 6 cm wide are common on bedding planes, suggesting a high-energy environment.

The middle part of the Gallup contains locally abundant, small-scale herringbone crossbeds suggesting tidal channels. Ripple laminations are common in beds adjacent to those that represent the tidal channels. Small brown concretions locally are abundant in the middle part of the Gallup; similar corrections have been seen forming in the present tidal zone of the southern Louisiana coast by the author.

The upper part of the Gallup consists of upper fine-grained sandstone containing large-scale trough crossbeds. The top of the Gallup weathers to rounded, knobby blocks, and the bedding surfaces are often covered with horizontal worm tubes resembling Ophiomorpha. No body fossils were found in the Gallup Sandstone in Pasture Canyon quadrangle.

Crevasse Canyon Formation

The Crevasse Canyon name was extended into the Datil Mountains coal field by Givens (1957). Givens and subsequent workers in the area included both the Crevasse Canyon Formation and the underlying Gallup Sandstone in the Mesaverde Group. Molenaar's (1983) suggestion that the Mesaverde Group nomenclature not be applied in west central New Mexico because of the geographic distance from the type area of the Mesaverde in the San Juan Basin as well as the age disparity will be followed in Pasture Canyon quadrangle.

Robinson (1981) and Massingill (1979) informally divided the Crevasse Canyon Formation in the Datil Mountains coal field into three units: a basal sandstone member, a medial interbedded shale and sandstone member, and an upper sandstone member. The middle and upper units roughly correspond to a transition from a coastal marsh and lagoon environment, including thin crevasse splays and lesser distributary channels, through a delta plain sequence to an upper, more inland, fluvial system. The lower sandstone member described by Massingill and Robinson is present in Pasture Canyon quadrangle and consists of 2-5 m (6-16 ft) of upper fine-grained sandstone that fines very slightly upward and is and usually interbedded with siltstones and mudstones. This sandstone is laterally persistent over 20 mi2 and can be observed both in outcrop exposures and recognized at depth on geophysical logs. This sandstone probably represents a beach ridge because of the relatively constant grain size and lateral persistence. This unit was too thin to be mapped separately from the fine-grained paludal rocks deposited in the coastal marsh.

The lower part on the Crevasse Canyon is dominated by dark to medium gray siltstones and mudstones with subordinate amounts of sandstones and coal. A coal zone is present from about 11 m to 122 m (35-400 ft) above the top of the Gallup Sandstone. The thickest coals in the section are concentrated in the lower 45 m

(15Ø ft) of the formation probably in interdistributary swamps. The middle part (152 m, 5ØØ ft) of the formation is nearly void of coal beds. The upper 6Ø m (2ØØ ft) of the formation contains infrequent discontinuous coal beds usually less than 3Ø cm (1 ft) thick. Total thickness of the Crevasse Canyon Formation is estimated at 434 m (1425 ft).

For mapping purposes, three assembleges of rocks were recognized: 1) a fine-grained unit made up of predominantly mudstones and siltstones with thin channel sandstones and coals, 2) individual channel sandstones greater than 2 m (6 ft) thick regardless of stratigraphic level of occurrence, and 3) a sandstone-mudstone assemblege in which vertically stacked sandstones greater than 2 m (6 ft) in thickness comprise 1Ø% or more of the unit. In general, the percentage of sandstone in the Crevasse Canyon Formation increases upward in the section as does the average thickness of each channel sandstone.

Buff-colored siltstone and silty mudstone and dark gray, carbonaceous shales comprise the predominant rock types in the fine-grained assemblege. Nearly all the coal and organic matter in the Crevasse Canyon Formation are present in this unit. Coalified and petrified logs and plant fragments are locally abundant, especially adjacent to coal beds. Dark brown to purple, silicified or calcareous concretions from 3 to 6Ø cm (1-25 in) in diameter are common below coal beds and in distinct zones occurring at 12Ø m (4ØØ ft) and 15Ø m (5ØØ ft) above the base of the formation. Between 5 and 1Ø % of the fine-grained facies is made up of thin (<2 m thick) sandstones representing primarily overbank deposits, crevasse splays, and small anastomosing streams similar to those described in the Niger River (Allen, 1965) and some parts of the Mississippi River (Coleman and Gagliano, 1965) delta plains.

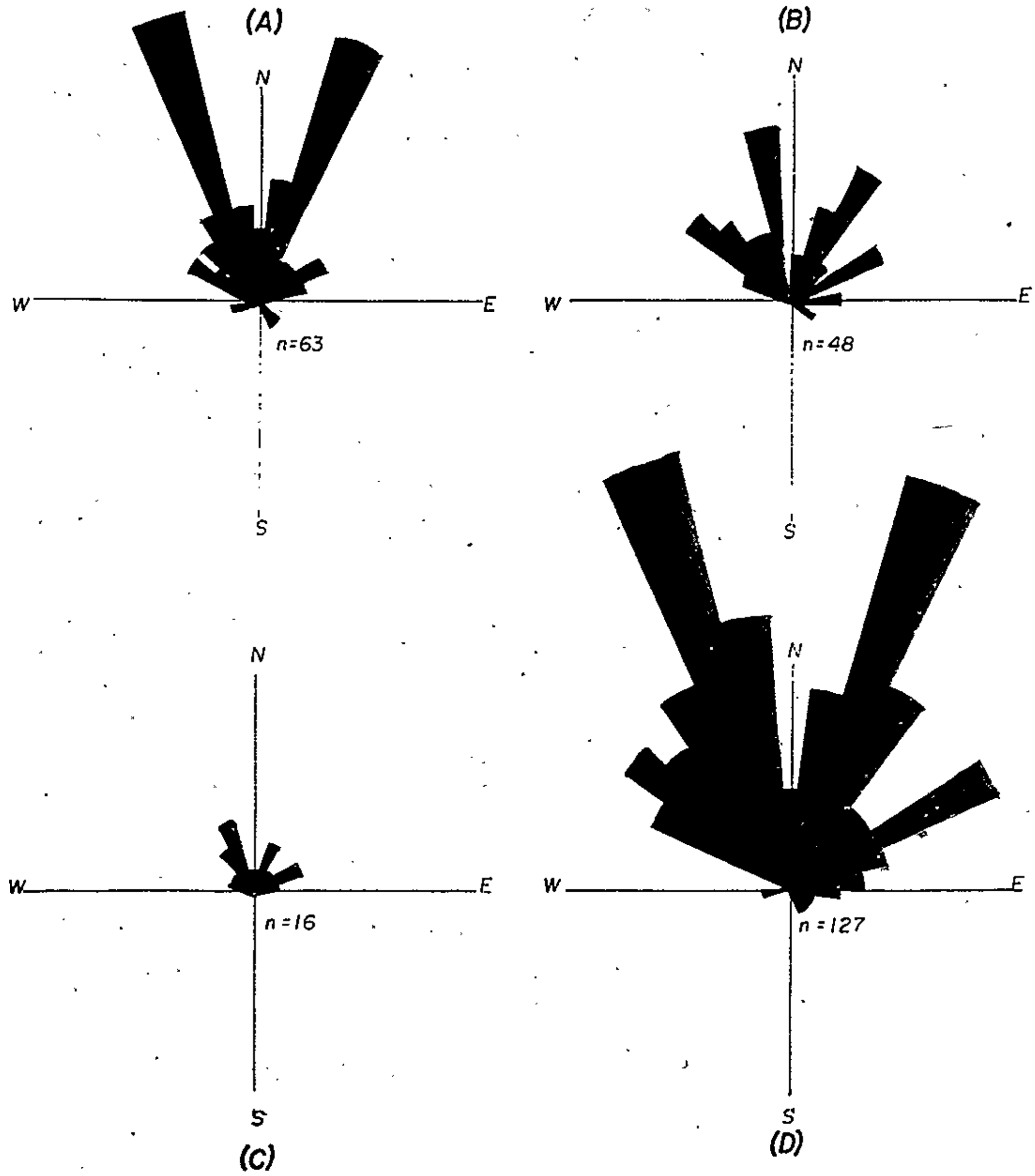
Most of the sandstones in Pasture Canyon quadrangle are fluvial in nature and range from thin, individual channels less than 2 m thick (6 ft) concentrated in the lower part of the formation to stacked-channel sequences up to 15 m (50 ft) thick in the upper part of the formation. The sandstones represent small low-sinuousity channels, crevasse-splay deposits, overbank sandstones, and larger distributary channels. The relationships between the various sandstones are displayed in exposures on the sides of high mesas in Pasture Canyon quadrangle where in many exposures thick sandstone are flanked by thinner sandstones in a "beaded" arrangement suggesting distribatary channels and adjacent overbank deposits.

The increase in average grain size and gradual thickening of the sandstones upsection probably represents an upward transition to the landward reaches of the coastal plain. In this environment, sandstones could migrate laterally for long distances with only thin point bar deposits to mark the stream's progress. Alternately, more sand could have been available as a result of Laramide tectonic uplift and more vigorous erosion in source areas to the south and west. Upward coarsening has been observed further to the east in the Datil Mountains coal field (Osburn, 1982) and to the south in the Engle coal field (Wallin, 1983). Detailed petrographic study of the sandstones in the Crevasse Canyon Formation, in progress by S. Johanson, University of Texas at Austin, should enlighten Cretaceous workers as to both the sand source and possible tectonic implications.

Similar sedimentary structures are present in all of the channel sandstones, regardless of thickness or areal extent. Grain size ranges from lower very fine grained to lower medium grained sandstone in the channels. From bottom to top of each channel, the idealized sedimentary sequence consists first of a sharp scoured base, a basal, poorly sorted interval with 6-10 mm mudclasts derived from the muddy substrate, and abundant organic debris including stems and leaf fragments. This basal part grades up into moderately sorted light brown, wedge planar crossbedded sandstone, topped by small scale trough crossbeds. Planar laminations and ripple laminations complete the channel sequence. The channel sequence can be as little as 1 m (3 ft) thick and up to 6 m (20 ft) thick and is often present in stacked-channel cycles. The sequence generally fines upward and bedding thins upward within each cycle.

Paleocurrent directions were measured on crossbeds in various types of channel sandstones including thin splay sandstones present in the mudstone-dominated facies, individual sandstones thicker than 2 m (6 ft) throughout the stratigraphic section, and in the stacked sandstones present in the upper part of the formation. Results are presented as paleocurrent rose diagrams for each type of channel sandstone and as a composite for all measurements (fig. 5). Crossbed dip directions in all three types of channels suggest that flow was generally to the north. The paleocurrent indicators are remarkably unimodal with direction spread of 255° in the overbank and splay sandstones,

Figure 5 - Rose diagrams of paleocurrent indicators measured on planar and trough crossbeds in the Crevasse Canyon Formation. Measurements are grouped by assembleges into (a) thin sandstones of the mudstone-dominated unit, (b) individual channel sandstones > 2 m thick, and (c) sandstone-prevalent unit. Sketch (d) is a composite of all measurements and shows the unimodal pattern of all transport indicators.



185^{o} in the larger individual channels, and 120^{o} in the sandstone-prevalent assemblege respectively. The amount of spread in the overbank and splay deposits is typical for overbank deposits but the average direction of transport nearly parallels the transport direction of the larger channels, rather than being normal to the larger channels as expected for a feature that forms as a result of bank failure. The seaward gradient on the coastal plain must have been sufficient to affect the current flow in the small channels.

Tertiary System

Spears Formation

The Spears Formation is a regionally persistent volcanic unit in the Datil, Gallinas, and Bear Mountains. The Spears is restricted to the extreme southeast corner of Pasture Canyon quadrangle on the east side of the Red Lake fault. The unit in the study area is light-gray ash-flow tuff and light-pink volcaniclastic rocks. Exposure of the Spears Formation in Pasture Canyon is poor probably because of small faults adjacent to the major Red Lake fault.

Intrusive basaltic rocks

Bell Mountain is a prominent volcanic neck in the northeastern corner of Pasture Canyon quadrangle. The neck exhibits classic columnar jointing, especially on the north and south sides. Two northwest-trending dikes intrude the Crevasse Canyon Formation in the east half of Pasture Canyon quadrangle.

Both dikes parallel one of two major faults on the quadrangle. The northern dike continues almost uninterrupted for 6 mi in Pasture Canyon quadrangle and then continues northward at least 2 mi. Both dikes are tabular, 1-3-m-wide features with a thin, baked zone that extends into the host rock. The cores of both dikes make up a sugary textured, porphyritic rock that is less resistant than the chill margins and that forms topographic depressions.

Quaternary System

Quaternary deposits in Pasture Canyon quadrangle consist of water-laid sediments (Qvy, Qpy, and Qsg) and landslide deposits derived from Bell Mountain and Cretaceous sandstones (Qls). Quaternary valley alluvium outside epmeral streams primarily transported by sheet flood during torrential summer storms. Piedmont slope deposits consist of fanglomerates containing both Cretaceous sandstone clasts and volcanic clasts presumably derived from the south. These piedmont slope deposits are considered quite young because there is little or no soil development on these deposits. Quaternary deposits within active ephemeral channels range from mud to pebbles in grain size. The Alamocita Creek is a braided stream during the summer and reworks sand and gravel into a wide range of longitudinal, chute and point bars. During the dry season, strong winds change the stream deposits into a series of small sand dunes.

Coal Geology

Coals are concentrated in the lower part of the Crevasse Canyon Formation. Coal beds at the surface occur at a consistent interval above the shoreface deposits of the Gallup Sandstone (Plate 1). This seems consistent with coal deposition in coastal marshes on a lower delta plain.

Coal Resource Potential

Coal data for Pasture Canyon quadrangle is derived from three primary sources: outcrop measurements made during the 1982 field season by the author, unpublished field data (Winchester, 1913), and geophysical log interpretations from five holes drilled by Santa Fe, Inc. and provided to the author for study. Drill-hole coal locations can not be released at the present but information from the drill holes is used in resource calculations by township. Many of Winchester's (1913) outcrops (marked with a "W" on the map) have been severely eroded but have been included where field checking suggested the presence of a coalbed.

Resource calculations were compiled using methods described in U.S. Geologial Survey Bulletin 1450-B. All coal beds greater than 14 in thick were included in the calculations. Figures in this part of the report are presented in the English Standard system following convention. Demonstrated coal resources for Pasture Canyon quadrangle totaled to 30.03 million short tons (Table 1). About 10% of these resources are based on outcrop data.

Only two published proximate analyses are available for

Table 1 - Demonstrated coal resources in Pasture Canyon quadrangle, Catron County, New Mexico

(in millions of short tons)
updated 10/24/86

Location	Measured		Indicated	Demonstrated
	thickness of coal bed			
T.3N., R.9W.	1.2'-2.3'	2.3'-3.5'		
at surface	2.43	0.26	--	2.69
subsurface	0.57	2.02	19.07	21.66
				24.35
T.3N., R.10W.				
at surface	0.33	--	--	0.33
subsurface	0.68	--	4.67	5.35
				5.68
Totals	4.01	2.28	23.74	30.03

Pasture Canyon quadrangle (Table 2). These samples were taken by Winchester in 1913 at a prospect located in sec. 20, T.3N., R.9W. Today nothing remains to mark the site of the prospect. The heating values are very low and atypical of Datil Mountains coal, but because the samples were from weathered coals, these values should be considered minimum values. Recent analyses of coals collected about 10 mi east of Pasture Canyon have consistently shown that the Datil Mountains coals are bituminous in rank (Osburn, 1982).

The coals of Pasture Canyon represent a modest resource at best. Coal outcrops are continous over distances up to three miles along strike but are normally less than 3 ft (1 m) thick. Poor roads in the northeastern part of the quadrangle and the considerable distance from a railroad make transporation a serious problem. If transporation facilities existed, there would be a much greater chance of development. The structural simplicity of the area, i.e., extremely low dips and minimal faulting plus the predominance of fine-grained rocks make the area favorable for surface mining. Without adequate transporation, the most likely use for this coal would be local domestic heating fuel in this sparsely-populated region.

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Table 2 - Proximate analyses in Pasture Canyon Quadrangle at prospect located at NE1/4 NE1/4 SE1/4 sec. 2Ø, T.3N., R.9W. (Ellis, 1936)

Moisture	18.5	-
Volatile matter	31.7	38.9
Fixed carbon	39.Ø	47.8
Ash	1Ø.8	13.3
Sulfur	Ø.4	Ø.5
BTU/lb. (as received)	848Ø	1Ø,4ØØ

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GEOLOGIC MAP EXPLANATION

Quaternary Deposits

Qvy - young valley alluvium; includes gravel, sand, silt, and mud in flood plains, alluvial plains, and infilling behind slump blocks.

Qsg - sand, mud, and gravel deposits in active, ephemeral streams.

Qpy - piedmont-slope deposits on the current highlands with no appreciable soil development.

Qls - landslide debris derived from the Bell Mountain intrusive and Cretaceous sandstone.

Tertiary Deposits

Ti - mafic intrusive dikes and Bell Mountain intrusive neck.

Ts - SPEARS FORMATION: light gray ashflow tuff and light pink volcaniclastic rocks.

Cretaceous Deposits

CREVASSE CANYON FORMATION: Progradational sequence of interdistributary mudstones, siltstones with thin fluvial sandstones and coals grading up into vertically stacked sandstones of a fluvial system.

Kcm - fine-grained unit made up predominantly of mudstone and siltstones and coal with laterally discontinuous, thin channel sandstones comprising less than 10% of the unit.

Kcc - individual, laterally persistent channel sandstones greater than 2 m (6 ft) thick.

Kcs - sandstone-mudstone unit containing where channel sandstones greater than 2 m (6 ft) comprise at least 10% of the unit by volume.

Kg - GALLUP SANDSTONE: very fine-grained to fine-grained sandstone representing the upward change from lower to upper shoreface sedimentation.

Kmd - D-CROSS TONGUE OF THE MANCOS SHALE: bioturbated, fossilerous, locally calcareous shale.

SYMBOLS

geologic contact, dashed where approximate

fault, dashed where approximate, dotted where inferred

25 strike and dip of bedding

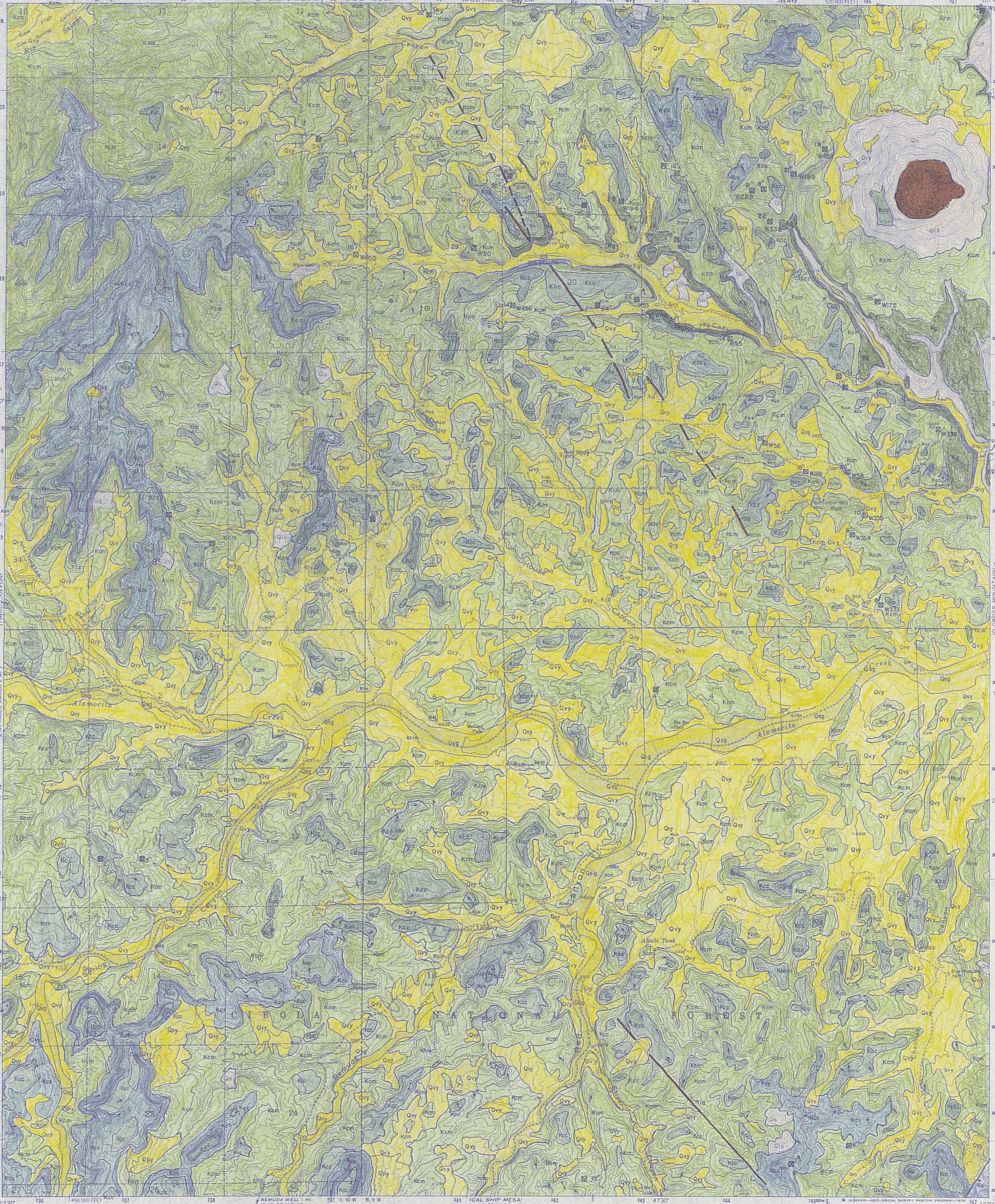
paleotransport indicators on crossbedding

24" W105 measured coals (outcrop) - number to the left of symbol is thickness in inches. Sample numbers prefixed with a "W" are from Winchester (1913). All locations have been field-checked.

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

Plate 1

PASTURE CANYON QUADRANGLE
NEW MEXICO–CATRON CO.
7.5 MINUTE SERIES (TOPOGRAPHIC)



Mapped, edited, and published by the Geological Survey

Control by USGS and USC&GS

Topography by photogrammetric methods from aerial photographs taken 1963. Field checked 1964

Polyconic projection. 1927 North American datum
10,000-foot grid based on New Mexico coordinate system, west zone
1000-meter Universal Transverse Mercator grid ticks, zone 13, shown in blue

Certain land lines are omitted because of insufficient data

UTM GRID AND 1964 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

SCALE 1:24 000

CONTOUR INTERVAL 20 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

THIS MAP COMPLIES WITH NATIONAL MAP ACCURACY STANDARDS
FOR SALE BY U. S. GEOLOGICAL SURVEY, DENVER, COLORADO 80225, OR RESTON, VIRGINIA 22092
A FOLDER DESCRIBING TOPOGRAPHIC MAPS AND SYMBOLS IS AVAILABLE ON REQUEST

NEW MEXICO
QUADRANGLE LOCATION

ROAD CLASSIFICATION
Unimproved dirt

PASTURE CANYON, N. MEX.
N3422.5–W10745/7.5
1964
AMS 4452 IV NE–SERIES V881