UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

MEASURED STRATIGRAPHIC SECTIONS OF THE UPPER COAL-BEARING PART OF THE CRETACEOUS MENEFEE FORMATION IN THE KIN KLIZHIN RUINS QUADRANGLE OF NORTHWESTERN NEW MEXICO

By

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This report is preliminary and has not been edited or reviewed for conformity with U.S. Geological Survey standards.

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MEASURED STRATIGRAPHIC SECTIONS OF THE UPPER COAL-BEARING PART OF THE CRETACEOUS MENEFEE FORMATION IN THE KIN KLIZHIN RUINS QUADRANGLE OF NORTHWESTERN NEW MEXICO

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INTRODUCTION

Stratigraphic sections of the upper part of the Upper Cretaceous Menefee Formation were measured during 1979 in the Kin Klizhin Ruins quadrangle (fig. 1) of northwestern New Mexico. The sections were measured in part to complement studies of coal bed distribution in the Menefee Formation in areas to the west in the Navajo Indian Reservation. Geologic interpretations of these measured sections are being reserved for a subsequent report. The sections are made available at this time to aid other studies of the resource potential of selected parts of the San Juan Basin that are in progress.

This report is a part of a regional study of the coal potential of the Navajo Indian Reservation and was done on behalf of the U.S. Bureau of Indian Affairs in cooperation with the Navajo Tribe.

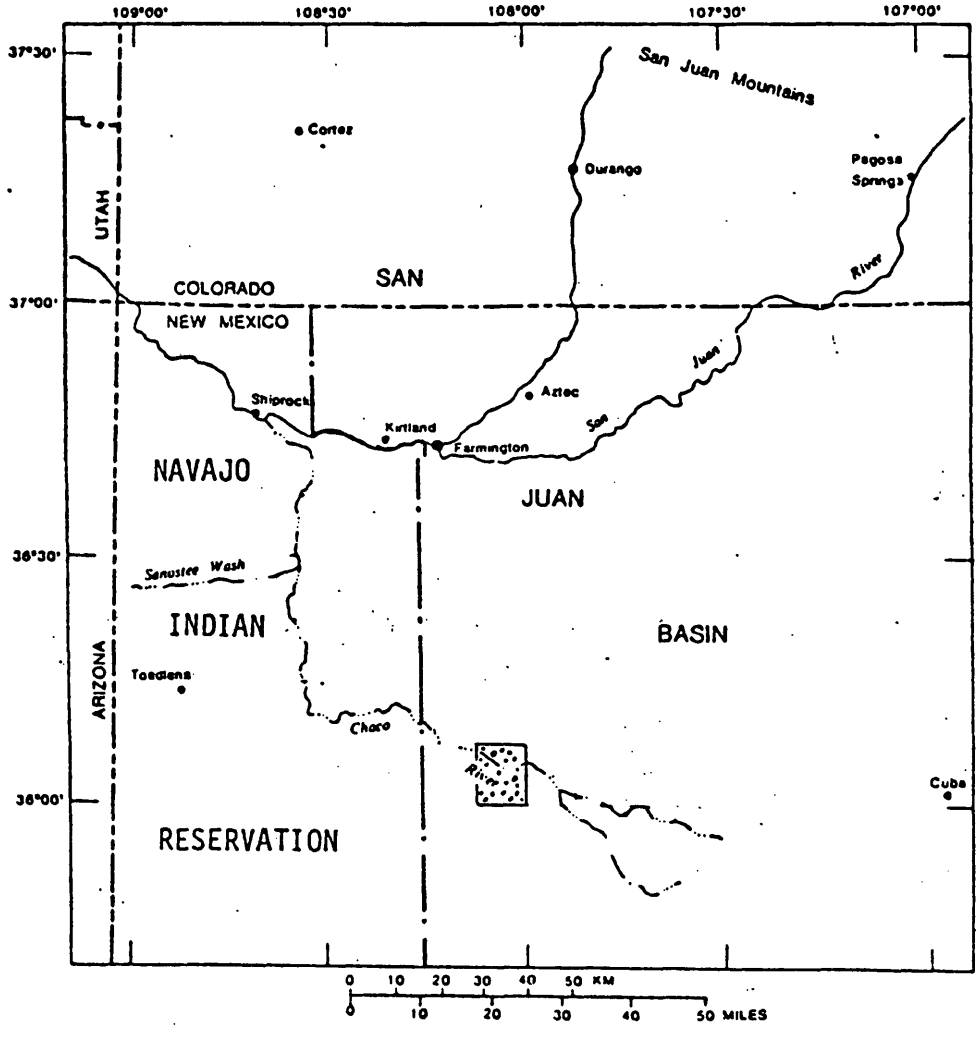


Figure 1.--Location of Kin Klizhin Ruins quadrangle (stippled).

MENEFEE FORMATION

The Menefee Formation of Late Cretaceous age is widespread in the San Juan Basin. The formation is coal-bearing at both the base and the top but is virtually barren of coal in the middle part. The lower and upper coal-bearing units contain brown and gray carbonaceous mudstone and shale and lenticular beds of sandstone and coal. The middle unit, which makes up by far the largest part of the Menefee, differs in that it contains only a few thin, economically unimportant coal beds, less carbonaceous mudstone and shale, and a greater proportion of sandstone beds. Individual beds in the formation are characteristically lenticular and discontinuous.

In the area near Kirtland, between the San Juan River and the Colorado State line, coal is present in the upper 250 feet of the Menefee Formation and constitutes the upper coal-bearing member of Hayes and Zapp (1955). They stated that "nearly two-thirds of the calculated coal reserves in the Menefee Formation (north of the San Juan River in New Mexico) are contained in the upper coal-bearing member." Along the south-trending course of the Chaco River, coal beds are locally abundant in the upper 250 feet of the Menefee; at other places the coal beds thin to near nonexistence. Coal beds are especially numerous and thick in the vicinity of Sanostee Wash. Along the eastward trending course of the Chaco River, the upper coal-bearing unit contains a few coal beds (some as much as 8 feet thick) that almost everywhere have been burned at the outcrop.

The Menefee Formation is present throughout the Kin Klizhin Ruins quadrangle. The overlying Upper Cretaceous Cliff House Sandstone and at places younger rocks conceal the Menefee locally in areas south of the Chaco River and more widely in areas north of the Chaco. The Menefee Formation in the Kin Klizhin Ruins quadrangle is probably about 2,500 feet thick; only the upper 500 to 600 feet, which includes the upper coal-bearing member, are exposed in the quadrangle.

The geology of the Kin Klizhin Ruins quadrangle is briefly discussed in two reports. A preliminary map (O'Sullivan and others, 1979) shows the distribution of rock units in the quadrangle. The coal geology is cursorily mentioned in a report by Shomaker, Beaumont, and Kottlowski (1971, p. 52-56). The measured stratigraphic sections are contained in Appendix A. The location of each measured section is shown on maps included in Appendix B. Measurements in this report are in feet; to convert to meters multiply by 0.3048.

REFERENCES CITED

Hayes, P. T., and Zapp, A. D., 1955, Geology and fuel resources of the Upper Cretaceous rocks of the Barker dome--Fruitland area, San Juan County, New Mexico: U.S. Geological Survey Oil and Gas Investigation Map OM-144.

O'Sullivan, R. B., Scott, G. R., and Weide, D. L., 1979, Preliminary geologic map of the Kin Klizhin Ruins quadrangle, San Juan and McKinley Counties, New Mexico: U.S. Geological Survey Miscellaneous Field Investigations Map MF-1094.

Shomaker, J. W., Beaumont, E. C., and Kottlowski, F. E., 1971, Strippable low-sulfur coal resources of the San Juan Basin in New Mexico and Colorado: New Mexico Bureau of Mines and Mineral Resources Memoir 25, 189 p.

APPENDIX A
Measured stratigraphic sections

SECTION K-1

[Measured in NE 1/4, sec. 36, T. 22 N., R. 12 W.]

	Thickness Feet
Cliff House Sandstone:	
5. Sandstone, light yellowish-gray----------	>10.0
Menefee Formation (a local tongue, incomplete):	
4. Sandstone, yellowish-brown and shale, gray, interbedded-	1.3
3. Shale, gray----------	2.1
2. Coal, impure; weathered----------	1.2
1. Shale, gray----------	>5.0

Note: Coal is in upper part of tongue of Menefee and grades north in a short distance into gray and brown shale. The tongue of the Menefee Formation nearby has chertified fossil wood.

SECTION K-2

[Measured in E 1/2, sec. 8, T. 21 N., R. 11 W.]

Cliff House Sandstone:	
35. Sandstone, yellowish-gray; forms a massive cliff-------	>50.0
Menefee Formation:	
34. Sandstone, yellowish-gray, abundant Ophiomorpha; forms a steep rubble covered slope up to unit 35----------	50.0
33. Shale, dark-brown to dark-gray, somewhat carbonaceous, resistant, fissile----------	3.5
32. Sandstone, gray; forms cliff----------	11.0
31. Shale, dark-brown to dark-gray and sandstone gray to dark-yellowish-brown; interbedded in very thin even beds 0.1-0.4 ft thick; forms slope and upper part is set in under unit 32----------	5.0
30. Sandstone, yellowish-gray; forms cliff----------	15.0
29. Shale, carbonaceous, black, resistant, fissile---------	0.8
28. Sandstone, yellowish-gray; forms ledge----------	3.1
27. Coal, very impure----------	0.9
26. Shale, carbonaceous, black; resistant; fissile---------	1.0
25. Sandstone, gray to yellowish-gray; forms slight ledge--	3.0
24. Shale, dark-brown; fissile; micaceous; resistant-------	1.2

SECTION K-2--Continued

		Thickness Feet
Menefee Formation--continued:		
23.	Sandstone, gray and yellowish-gray; some interbedded medium-gray shale and brown carbonaceous shale; forms steep slope----------	7.0
22.	Shale, carbonaceous, dark-gray, resistant; fissile-----	2.4
21.	Sandstone, yellowish-gray; friable; forms steep slope--	25.3
20.	Shale, carbonaceous, black----------	0.9
19.	Sandstone, light-gray and brown, mottled dark-yellowish-brown; forms cliff; no Ophiomorpha noted----------	40.0
18.	Shale, carbonaceous, black, resistant; poorly exposed because of cover from unit 19----------	5.0
17.	Shale, white; evenly bedded; only locally present------	0.3
16.	Coal; very impure----------	0.8
15.	Shale, medium-gray; forms slope----------	5.5
14.	Sandstone, yellowish-gray; forms slight ledge----------	3.2
13.	Shale, medium-gray; forms slope----------	3.0
12.	Shale, carbonaceous, black; resistant; forms slight ledge----------	3.1
11.	Shale, medium-gray; contains dense black irregularly shaped ironstone(?) nodules as much as 1.5 ft across, with calcite seams; unit forms slope----------	12.0
10.	Shale, dark-gray, somewhat carbonaceous throughout but basal 0.7 ft and top 1.3 ft are black carbonaceous shale beds like 7 that makes slight ledges, with middle part a slope----------	6.4
9.	Shale, light-gray to yellowish-gray; sandy; forms slope-	3.5
8.	Shale, medium-gray; slope----------	5.0
7.	Shale, carbonaceous, black and dark-brown; conspicious slight ledge----------	0.8
6.	Shale, medium-gray; forms slope----------	1.2
5.	Sandstone, yellowish-gray; basal 3 ft locally forms a ledge; rest forms a slope----------	10.0

SECTION K-2--continued

	Thickness Feet
Menefee Formation--continued:	
4. Shale, medium-gray, sandy; forms slope	6.7
3. Shale, carbonaceous, black; forms slight ledge	1.8
2. Shale, medium-gray	3.0
1. Sandstone, yellowish-gray; partly crossbedded, fluviatile; forms ledge	20.0

SECTION K-3

[Measured in SW 1/4, sec. 4., T. 21 N., R. 11 W.]

Menefee Formation:	
4. Sandstone, yellowish-gray; channels into coal of unit 3 with 3-4 inches of relief in 1-5 ft laterally; forms ledge	>5.0
3. Coal, weathered	0.8
2. Impure coal	1.6
1. Shale, carbonaceous, black and dark-gray; nonfissile; somewhat silty; base not exposed	5.0

SECTION K-4

[Measured in SW 1/4, sec. 4, T. 21 N., R. 11 W.; Section K-4 is about 150 ft south of Section K-3; section starts in alluvium but in beds that are stratigraphically lower than at Section K-3.]

Cliff House Sandstone:	
11. Sandstone, yellowish-gray; forms ledge	>30.0
10. Shale, carbonaceous, dark-gray; nonfissile	1.3
9. Sandstone, yellowish-gray; forms ledge	20.0
Menefee Formation:	
8. Impure coal--not present at Section K-3; probably cut out by unit 9	0.9
7. Coal same as unit 3 at Section K-3	0.5
6. Impure coal	1.2
5. Shale, carbonaceous, dark-gray; slightly fissile	7.0
4. Coal, brown; a 0.13 ft shale parting at 2.3 ft above base of unit	2.8

SECTION K-4--continued

	Thickness Feet
Menefee Formation--continued:	
3. Shale, carbonaceous, dark-gray; slightly fissile--------	2.6
2. Coal, weathered; poorly exposed; no partings noted	4.2
1. Shale, carbonaceous, dark-brown, to dark-gray; somewhat fissile; base not exposed----------	3.0

SECTION K-5

[Measured in SW 1/4, sec. 9, T. 21 N., R. 11 W]

Cliff House Sandstone:	
5. Sandstone, yellowish-gray; contains Ophiomorpha--------	Not measured
Menefee Formation(a local tongue);	
4. Shale, medium-gray----------	2.7
3. Shale, carbonaceous and a little impure coal, dark-gray to black----------	1.2
2. Poorly exposed, laterally interval is carbonaceous shale and some thin-lenticular impure coal----------	8.2
Cliff House Sandstone:	
1. Sandstone, light-gray----------	Not measured

SECTION K-6

[Measured in E 1/2, sec. 5, T. 21 N., R. 11 W.]

Cliff House Sandstone:	
12. Sandstone, yellowish-gray----------	>10.0
Menefee Formation:	
11. Shale, medium-gray; fissile; contains thin sandstone splits----------	4.6
10. Sandstone, gray; flat-bedded, basal part has numerous shale partings; forms ledge----------	1.7
9. Coal; a 0.1 ft clay parting at 0.5 ft above base; probably equivalent to unit 4 at Section K-4---------	1.8
8. Shale, carbonaceous, black----------	0.8
7. Shale, brown; fissile----------	3.3
6. Coal, very poorly exposed----------	1.5

SECTION K-6--continued

	Thickness Feet
Menefee Formation--continued:	
5. Shale, carbonaceous, black; fissile----------	0.7
4. Shale, dark-brown; slightly fissile----------	3.8
3. Sandstone, light-gray; friable; forms slope----------	5.3
2. Shale, carbonaceous, dark-gray; fissile; forms slight ledge----------	1.0
1. Shale, brown and gray; base not exposed----------	2.0

SECTION K-7

[Measured in SW 1/4, sec. 6, T. 21 N., R. 11 W.]

Menefee Formation (a local tongue):	
15. Shale, brown and carbonaceous shale----------	15.0
Cliff House Sandstone:	
14. Sandstone, yellowish-gray,----------	100.0
Menefee Formation:	
13. Shale, medium-gray, slightly fissile----------	1.0
12. Coal----------	0.7
11. Shale, carbonaceous, dark-brown to dark-gray; fissile; resistant; slight ledge; a 0.1 ft coal at 19.1 ft above base underlain by 0.7 ft of soft impure coal--	24.0
10. Sandstone, light-gray; forms slight ledge----------	3.0
9. Shale, medium-gray; forms slope----------	2.5
8. Shale, dark-brown, slightly carbonaceous; fissile------	2.4
7. Shale, medium-gray; forms slope; contains large ironstone concretion 1-2 ft across----------	5.4
6. Shale, carbonaceous and coaly; slightly fissile--------	1.0
5. Shale, medium-gray; forms slope; contains thin gray friable sandstone beds----------	6.2
4. Sandstone, yellowish-gray; friable; but locally forms slight ledge; middle part contains large rounded concretion as much as 4 ft across by 2 feet thick---	10.0
3. Shale, medium-gray; forms slope----------	6.1
2. Shale, carbonaceous, black; slightly fissile----------	1.0
1. Shale, medium-gray; base not exposed----------	3.0

SECTION K-8

[Measured in SW 1/4, sec. 16, T. 21 N., R. 11 W.]

		Thickness Feet
Cliff House Sandstone:		
43.	Sandstone, yellowish-gray; forms cliff----------	>30.0
Menefee Formation:		
42.	Shale, medium-gray to brown----------	2.4
41.	Sandstone, yellowish-gray; forms ledge----------	3.3
40.	Shale, carbonaceous----------	10.8
39.	Sandstone, light-gray; forms ledge----------	6.3
38.	Coal; poorly exposed; badly weathered----------	3.1
37.	Shale, carbonaceous----------	3.5
36.	Sandstone, light-gray to dark-yellowish-gray; forms slight ledge----------	0.6
35.	Shale, carbonaceous----------	2.3
34.	Sandstone, light-gray; forms slight ledge----------	0.4
33.	Shale, carbonaceous----------	0.3
32.	Sandstone, light-gray; forms slight ledge----------	0.3
31.	Shale, carbonaceous, dark-brown, weathers dark-gray; slightly coaly----------	0.9
30.	Shale, medium-gray to brown; forms slope----------	6.0
29.	Sandstone, dark-yellowish-gray; friable; forms slope---	21.0
28.	Sandstone, light-yellowish-gray to light-gray; crossbedded; forms ledge----------	10.0
27.	Shale, carbonaceous, dark-gray; fissile; much of it is clinkered, particularly the upper 2 ft----------	4.5
26.	Shale, brown to medium-gray; forms slope----------	6.0
25.	Shale, carbonaceous, very dark brown, weathers dark-gray; coaly----------	5.0
24.	Sandstone, yellowish-gray; forms ledge----------	3.4
23.	Shale, medium-gray; forms slope----------	6.3
22.	Sandstone, yellowish-gray; friable; conspicuous marker bed at this locality----------	11.0
21.	Shale, carbonaceous, very dark brown, weathers dark-gray; coaly; fissile; forms ledge----------	1.8

SECTION K-8--continued

		Thickness Feet
Menefee Formation--continued:		
20.	Shale, medium-gray; forms slope----------	2.4
19.	Sandstone, yellowish-gray; forms ledge----------	2.3
18.	Shale, medium-gray; forms slope----------	1.3
17.	Shale, carbonaceous, very dark brown, weathers dark-gray; coaly; fissile; forms ledge----------	2.2
16.	Shale, medium-gray; forms slope----------	1.7
15.	Shale, carbonaceous, very dark brown; coaly; fissile--	0.8
14.	Shale, medium-gray; forms slope----------	0.5
13.	Sandstone, yellowish-gray; some thin-bedded gray shale; forms ledge; upper 5 ft soft and benched back----------	20.0
12.	Shale, medium-gray; forms slope; contains some lenticular yellowish-gray sandstone beds----------	8.6
11.	Shale, carbonaceous, very dark brown, weathers dark-gray; fissile; forms ledge----------	1.2
10.	Shale, medium-gray----------	2.1
9.	Sandstone, yellowish-gray; forms ledge----------	2.6
8.	Shale, medium-gray; forms slope----------	2.4
7.	Shale, carbonaceous; very dark brown; contains little blebs of vitreous coal----------	2.5
6.	Sandstone, yellowish-gray; forms slight ledge--------	8.5
5.	Shale, medium-gray----------	6.7
4.	Sandstone, yellowish-gray; friable; locally makes slight ledge----------	3.7
3.	Shale, carbonaceous, very dark brown; shaley; fissile; forms slope----------	0.8
2.	Sandstone, yellowish-gray; forms ledge; in vicinity caps small nearby mesas; grades laterally into medium-gray shale----------	5.0
1.	Shale and sandstone, medium-light-gray; interbedded; base concealed----------	10.5

SECTION K-9

[Measured in NW 1/4, sec. 21, T. 21 N., R. 11 W.]

		Thickness Feet
Cliff House Sandstone:		
38.	Sandstone, burned red to reddish-brown----------	>40.0
Menefee Formation:		
37.	Clinker bed, hard, baked shale; somewhat fissile and splits into thin plates----------	21.0
36.	Shale, medium-gray; forms slope----------	0.8
35.	Shale, carbonaceous, black; fissile; forms ledge-----	1.3
34.	Shale, medium-gray; forms slope----------	6.5
33.	Sandstone, light-gray; forms ledge----------	1.5
32.	Shale, medium-gray; forms slope----------	2.2
31.	Sandstone, light-gray; friable----------	4.0
30.	Shale, medium-gray; forms slope----------	10.0
29.	Sandstone, yellowish-gray; friable----------	9.5
28.	Shale, medium-gray; forms slope----------	2.8
27.	Shale, carbonaceous----------	1.2
26.	Shale, medium-gray; forms slope----------	5.0
25.	Shale, carbonaceous; forms slight ledge----------	0.7
24.	Shale, brown; forms slope----------	15.0
23.	Sandstone, yellowish-gray; forms ledge in lower half; upper half forms slope----------	11.5
22.	Shale, medium-gray; forms slope; a yellowish-gray sandstone about 1 ft thick, 2 ft from top---------	11.8
21.	Sandstone, yellowish-gray; friable----------	1.5
20.	Shale, medium-gray; forms slope----------	2.6
19.	Shale, carbonaceous; conspicuous slight ledge--------	1.2
18.	Shale, medium-gray; forms slope----------	7.2
17.	Shale, carbonaceous, medium-gray; forms slope---------	0.8
16.	Shale, medium-gray; forms slope----------	1.3
15.	Sandstone, yellowish-gray; friable----------	1.3
14.	Shale, medium-gray; forms slope----------	9.0
13.	Sandstone, yellowish-gray, friable; locally forms ledge----------	5.0

SECTION K-9--continued

		Thickness feet
Menefee Formation--continued:		
12.	Shale, medium-gray; forms slope----------	3.3
11.	Shale, carbonaceous----------	1.0
10.	Shale, medium-gray; forms slope----------	1.1
9.	Sandstone, yellowish-gray; friable----------	2.3
8.	Shale, medium-gray; forms slope; contains ironstone concretions; a few thin sandstone lenses----------	13.5
7.	Sandstone, yellowish gray; forms ledge----------	1.3
6.	Shale, medium-gray; forms slope----------	3.4
5.	Sandstone, yellowish-gray; friable----------	3.0
4.	Shale, medium-gray; contains ironstone concretions; some thin lenticular interbedded yellowish-gray sandstone----------	10.0
3.	Shale, carbonaceous----------	1.3
2.	Sandstone, very light-yellowish-gray; friable--------	0.5
1.	Shale, medium-gray; base not exposed----------	2.0

SECTION K-10

[Measured in NE 1/4, sec. 21 and NW 1/4, sec. 22, T. 21 N., R. 11 W.]

Cliff House Sandstone:		
33.	Sandstone, lower 15 ft yellowish-gray, rest light-gray; forms cliff and top of mesa----------	>60.0
Menefee Formation (a local tongue):		
32.	Shale, brown and gray; forms slope; contains one thin interbedded sandstone----------	8.4
31.	Shale, carbonaceous----------	2.0
30.	Impure coal----------	1.3
29.	Shale, carbonaceous----------	0.8
28.	Shale, brown and gray; forms slope----------	14.4
27.	Coal----------	1.6
26.	Shale, carbonaceous----------	0.8
25.	Shale, brown; forms slope----------	9.1
24.	Sandstone, brown; forms ledge with a bench on top----	1.1
23.	Shale, brown and gray; forms slope----------	10.0

SECTION K-10--continued

	Thickness Feet
Menefee Formation--continued:	
22. Coal----------	0.8
21. Shale, brown; poorly exposed----------	1.0
Cliff House Sandstone (a local tongue):	
20. Sandstone, brown and gray; Ophiomorpha present 5 ft above base----------	160.0
Menefee Formation:	
19. Coal, poorly exposed----------	1.0
18. Shale, carbonaceous----------	2.7
17. Shale, brown; forms slope----------	5.0
16. Shale, brown, weathers medium-gray; chunky; abundant plant impressions; a light-gray bench at top because upper part of unit is slightly silty to very fine sandy----------	1.7
15. Sandstone, yellowish-gray to brown; forms ledge------	10.3
14. Shale, brown; locally forms a clinker bed----------	2.8
13. Coal; poorly exposed; burned----------	2.6
12. Shale, carbonaceous----------	1.8
11. Coal; poorly exposed----------	1.0
10. Shale, brown; forms slope----------	6.5
9. Sandstone, gray; friable; seamed with gypsum---------	1.2
8. Shale, carbonaceous----------	3.3
7. Shale, brown; chunky; forms slope----------	3.0
6. Sandstone, yellowish-gray; friable----------	2.5
5. Shale, carbonaceous----------	1.7
4. Sandstone, yellowish-gray; friable----------	3.8
3. Shale, dark-brown; abundant plant fragment impressions; chunky; forms slight ledge----------	0.8
2. Shale, medium-gray; forms slope----------	5.0
1. Sandstone, yellowish-gray; friable; base not exposed-	6.5

Note: Where section K-10 was measured, the beds below unit 20 are not burned but are equivalent to beds at Section K-9, unit 37 that are burned.

SECTION K-11

[Measured in NE 1/4, sec. 14, T. 21 N., R. 12 W.]

		Thickness Feet
Menefee Formation (part):		
10.	Shale, gray overlain by thin sandstone; unit caps top of mesa----------	>5.0
9.	Limestone; brown; concretionary, dense; makes ledge---	2.0
8.	Shale, gray; forms slope----------	7.7
7.	Sandstone, gray; forms ledge----------	2.8
6.	Coal, impure----------	0.6
5.	Shale, gray to brown; forms slope----------	1.7
4.	Coal----------	0.6
3.	Shale, gray; forms slope; ironstone concretions at base; a 0.5-ft gray sandstone makes ledge 4 ft above base----------	7.3
2.	Shale, carbonaceous, black; grades to impure coal----	0.9
1.	Shale, brown and gray; forms slope; base concealed---	3.0

SECTION K-12

[Measured in SE 1/4, sec. 10, T. 21 N., R. 12 W.]

Menefee Formation:		
28.	Shale and sandstone; lower 5 ft baked shale, rest gray thin-bedded sandstone to top of hill and end of section----------	8.0
27.	Shale, gray; forms slope----------	5.2
26.	Shale, carbonaceous----------	4.8
25.	Sandstone, light-gray; very thinly bedded----------	0.8
24.	Shale, carbonaceous----------	1.2
23.	Shale, gray; thin sandstone stringers; forms slope---	11.0
22.	Shale, carbonaceous, brown to black----------	1.6
21.	Sandstone, light-gray; friable----------	4.9
20.	Shale, gray, forms slope----------	5.0
19.	Sandstone, yellowish-gray in lower part, light-gray above; crossbedded; forms cliff----------	17.0
18.	Shale, gray; interbedded thin yellowish-gray sandstone; ironstone concretions in lower half----	8.5

SECTION K-12--continued

	Thickness Feet
Menefee Formation--continued:	
17. Shale, carbonaceous, dark-gray; conspicuous limonitic staining on joints----------	0.8
16. Shale, gray; forms slope----------	10.4
15. Sandstone, yellowish-gray; crossbedded; forms ledge--	4.1
14. Shale, carbonaceous; some thin bright coal fragments; upper 0.4 ft is gray noncarbonaceous shale--------	2.3
13. Sandstone, yellowish gray and gray shale, interbedded; thinly bedded in beds 1-2 ft thick; some sandstone beds appear to be channeling----------	16.7
12. Shale, carbonaceous, dark-gray; contains thin streaks of bright coal----------	2.3
11. Shale, gray; forms slope----------	7.0
10. Shale, carbonaceous, dark-gray----------	1.4
9. Shale, gray; forms slope; ironstone concretion in upper part----------	10.5
8. Sandstone, yellowish-gray; friable----------	4.4
7. Shale, gray; forms slope----------	21.0
6. Sandstone, yellowish-gray; upper part in this area has rounded dark brown concretion masses; base is sharp; forms ledge; flat-bedded; very conspicuous in this area but is one of several similar beds some of which cap small flat-topped mesas; top appears gradational and is friable; unit lenticular and disappears 200 ft to northeast but a similar sandstone at same level is present on the isolated mesa about 350 ft to the north----	6.2
5. Shale, gray; contains thin interbedded friable sandstone ----------	46.0
4. Sandstone, light-gray; friable----------	1.5
3. Shale, gray; brown to black; contains ironstone concretions----------	5.8
2. Sandstone, light-gray; friable----------	1.6
1. Shale, gray; base is concealed in alluvium----------	3.0

SECTION K-13

[Measured in SW 1/4, sec. 3, T. 21 N., R. 12 W.]

	Thickness Feet
Cliff House Sandstone:	
27. Sandstone, light-yellowish-gray; abundant Ophiomorpha; forms cliff	>50.0
Menefee Formation (a local tongue):	
26. Shale, carbonaceous, black	1.3
25. Coal, subvitreous	1.4
24. Shale, carbonaceous, black to dark-brown; resistant	15.0
23. Shale, carbonaceous, dark-brown to light-brown; poorly exposed in a covered slope	15.0
Cliff House Sandstone (a local tongue):	
22. Sandstone, yellowish-gray; series of lenticular ledge forming sandstones in lower 10 ft; rest is friable; contains ironstone concretion	25.0
Menefee Formation:	
21. Shale, carbonaceous, dark-brown to gray	10.0
20. Coal; in ascending order; 0.7 ft black impure coal, 0.4 vitreous coal	1.1
19. Shale, carbonaceous, dark-brown to dark-gray	5.1
18. Shale, brown, weathers bluish-gray; abundant plant fragments	5.8
17. Sandstone, light-gray and interbedded gray shale in very thin beds	10.5
16. Shale, gray; forms a little cliff under unit 17	1.6
15. Shale, carbonaceous, dark-gray to black	0.8
14. Shale, brown; nodular; forms a cliff	5.9
13. Shale, gray and interbedded thin gray sandstone; contains ironstone concretions all through unit; forms slope	17.0
12. Shale and coal; in ascending order 0.5 ft black carbonaceous shale, 0.3 ft bright vitreous coal, 0.2 ft dark-gray carbonaceous shale	1.0

SECTION K-13--continued

	Thickness Feet
Menefee Formation--continued:	
11. Shale, gray; slightly carbonaceous zone 0.3 ft near middle of unit	3.6
10. Sandstone, yellowish-gray; crossbedded; forms ledge	11.0
9. Shale, gray	1.2
8. Shale, carbonaceous, dark-gray to black	2.4
7. Shale, gray; forms slope	12.8
6. Sandstone, yellowish-gray; friable	3.8
5. Shale, gray; forms slope	6.2
4. Shale, carbonaceous, brownish-black; very continuous in this area	1.1
3. Shale, gray; forms slope	2.4
2. Sandstone, yellowish-gray; friable but makes a slight cliff	17.8
1. Shale, gray; base is concealed in alluvium	2.5

SECTION K-14

[Measured in NE 1/4, sec. 4, T. 21 N., R. 12 W.]

Cliff House Sandstone (a local tongue):	
18. Sandstone, light-brown; forms ledge	10.0
Menefee Formation:	
17. Shale, baked red	7.0
16. Shale, light-gray; very friable almost an ash	0.7
15. Shale, carbonaceous, black to dark-gray; resistant	7.8
14. Sandstone, yellowish-gray to light-gray; contains some gray shale near base	1.8
13. Shale, carbonaceous, black; resistant; forms slight ledge	2.1
12. Shale, gray; forms slope	14.2
11. Shale, carbonaceous, dark-brown; resistant; forms slight ledge	1.2
10. Shale, gray; forms slope	1.0
9. Sandstone, light-gray; forms ledge	11.0

SECTION K-14--continued

	Thickness Feet
Menefee Formation--continued:	
8. Shale, gray; locally contains gray sandstone lenses; a 0.6 ft dark-brown carbonaceous shale with very thin coal streaks at 9.9 ft above base; forms slope----------	11.2
7. Sandstone, yellowish-gray; forms ledge----------	2.0
6. Shale, carbonaceous, dark-brown; resistant; forms slight ledge----------	1.5
5. Shale, gray; forms slope----------	15.6
4. Sandstone, light-gray; base sharp; top gradational; forms ledge----------	8.0
3. Shale, gray; a 1.5-ft light-gray sandstone at 4 ft above base; forms slope----------	6.4
2. Shale, carbonaceous, dark-gray; forms slight ledge---	0.5
1. Shale, gray and thin light-gray sandstone beds; forms slope; base concealed in alluvium----------	8.0

SECTION K-15

[Measured in SE 1/4, sec. 34, T. 22 N., R. 12 W.]

Cliff House Sandstone:	
27.--Sandstone, yellowish-gray to light-brown; top eroded; same as unit 27 of Section K-13; the tongue of Cliff House Sandstone, unit 22 of Section K-13, pinches out northward and is absent here at Section K-15--	>10.0
Menefee Formation:	
26. Shale, gray; forms cliff set in under unit 27--------	5.1
25. Coal, dull----------	0.6
24. Shale, carbonaceous, gray to dark-brown; hard; forms ledge----------	0.7
23. Shale, gray; forms slope----------	7.4
22. Sandstone, light-gray; flat-bedded; forms ledge-----	4.1
21. Shale, gray; forms slope----------	10.1
20. Sandstone, yellowish-gray; forms ledge; very lenticular and pinches out southward----------	5.0

SECTION K-15--continued

		Thickness Feet
Menefee Formation--continued:		
19.	Shale, gray; makes re-entrant under unit 20----------	1.2
18.	Coal, dull; no partings noted----------	1.4
17.	Shale, carbonaceous, dark-brown to dark-gray; resistant forms slight ledge----------	1.2
16.	Shale, gray; forms slope----------	3.1
15.	Coal; both dull and bright vitreous; no partings noted	2.1
14.	Shale, carbonaceous, dark-gray, resistant forms slight ledge----------	1.3
13.	Shale, gray to yellowish-gray; contains thin sandstone interbeds; forms slope----------	16.0
12.	Shale, dark-brown; contains carbonaceous chips; forms slope----------	1.7
11.	Sandstone, light-gray; in several irregular beds separate by gray or brown shale beds----------	9.3
10.	Shale, dark-gray, with thin light-gray sandstone streaks; unit very regularly bedded; shale fissile	4.6
9.	Sandstone, light-gray and shale medium-gray; interbedded in thin even beds as much as 0.2 ft thick----------	10.1
8.	Sandstone, light-gray and thin gray shale streaks; friable----------	3.1
7.	Shale, carbonaceous, dark-gray to black----------	2.4
6.	Shale, gray; forms slope----------	7.0
5.	Sandstone, yellowish-gray; crossbedded; forms ledge--	11.0
4.	Shale, dark-brown; flecks of carbonaceous trash------	2.8
3.	Shale, gray; forms slope----------	2.6
2.	Shale, carbonaceous, dark-brown to dark-gray; coal streak at top locally; resistant; forms slight ledge----------	3.3
1.	Shale, gray; forms slope; base concealed in alluvium-	3.0

SECTION K-16

[Measured in SW 1/4, sec. 27 and SE 1/4, sec. 28, T. 22 N., R. 12 W.]

	Thickness Feet
Cliff House Sandstone:	
24. Sandstone, light-gray; Ophiomorpha abundant throughout unit; forms ledge; a dark-brown ledge 1.5 ft thick caps mesa and contains fossil hash. Top of mesa covered with thin veneer of white quartzite, red and black cherts as much as 3 inches across-------	110.0
Menefee Formation (a local tongue):	
23. Shale, brown and gray; forms slope----------	15.2
22. Coal, dull----------	1.6
21. Shale, carbonaceous, black; resistant----------	0.6
20. Shale, brown; forms slope----------	6.3
Cliff House Sandstone (a local tongue):	
19. Sandstone, yellowish-gray; ledge; above 90 ft sandstone is light gray; Ophiomorpha are abundant-----	185.0
Menefee Formation (a local tongue):	
18. Shale, gray; contains thin even-bedded yellowish-gray sandstone stringers----------	2.1
17. Coal, subvitreous----------	2.4
16. Shale, carbonaceous, gray to black; resistant--------	13.8
15. Sandstone, gray; forms slight ledge, with a broad bench on top----------	1.7
14. Shale, brown and gray; forms slope----------	5.9
13. Sandstone, yellowish-gray; friable----------	3.2
12. Shale, dark-brown; resistant----------	1.3
Cliff House Sandstone (a local tongue):	
11. Sandstone, brown near base, light-gray at top; forms ledge----------	25.0
Menefee Formation:	
10. Shale, carbonaceous, dark-brown to dark-gray; resistant----------	7.1
9. Sandstone, light-yellowish-gray; forms slight ledge--	0.7

SECTION K-16--continued

	Thickness Feet
Menefee Formation--continued:	
8. Shale, carbonaceous, dark-gray to black; contains thin coal streaks	1.8
7. Shale, brown; contains some thin sandstone lentils; forms slope	13.2
6. Sandstone, yellowish-gray; forms ledge; channeling base	5.2
5. Shale, brown and gray; contains interbedded sandstone; forms slope	9.5
4. Coal; in ascending order 0.7-ft dull coal, 1.1-ft shaley coal, 0.8-ft dull coal; unit 4 pinches out abruptly to east	2.6
3. Shale, carbonaceous, dark-gray to black	7.7
2. Shale, carbonaceous, dark-gray, dark-brown and light-gray; thinly bedded; resistant; forms slight ledge	11.5
1. Sandstone, yellowish-gray; friable; base concealed in alluvium	30.0

SECTION K-17

[Measured in NE 1/4, sec. 27, T. 22 N., R. 12 W.]

Cliff House Sandstone (a local tongue):	
12. Sandstone, light-brown; forms cliff	>10.0
Menefee Formation:	
11. Shale, gray; contains thin yellowish-gray sandstone streaks	7.4
10. Shale, carbonaceous, dark-gray to black; resistant	1.4
9. Coal, dull	2.2
8. Shale, carbonaceous, dark-gray to black; resistant	3.5
7. Shale, brown; evenly bedded; forms slope	10.0
6. Coal, subvitreous	0.9
5. Impure coal; shaley	0.5

SECTION K-17--continued

	Thickness Feet
Menefee Formation--continued	
4. Shale, brown----------	0.4
3. Coal, dull; slightly shaley----------	0.2
2. Shale, carbonaceous, black to dark-gray, some brown very thin coal streaks----------	0.6
1. Shale, brown, evenly bedded, forms slope; base concealed in alluvium----------	17.0

SECTION K-18

[Measured in SE 1/4, sec. 26, T. 22 N., R. 12 W.]

Cliff House Sandstone:	
10. Sandstone, light-brown; forms ledge----------	>10.0
Menefee Formation:	
9. Shale, gray; set back under unit 11----------	1.4
8. Shale, carbonaceous, black; upper 0.4 ft is coaly----	1.8
7. Shale, brown; thin sandstone beds in lower part; upper 3 ft is medium dark gray; fissile shale----------	10.0
6. Shale, carbonaceous; dark-gray to gray; resistant; forms slight ledge----------	0.6
5. Coal, shaley; thin black vitreous streaks at top and bottom----------	0.8
4. Shale, carbonaceous, dark-gray to black; resistant---	5.0
3. Shale, brown; contains thin yellowish-gray sandstone beds; forms slope----------	5.0
2. Shale, carbonaceous; dark-gray; resistant; forms a slight ledge----------	1.1
1. Shale, brown; evenly bedded; forms slope----------	11.5

SECTION K-19

[Measured in NE 1/4, sec. 34, T. 22 N., R. 12 W.]

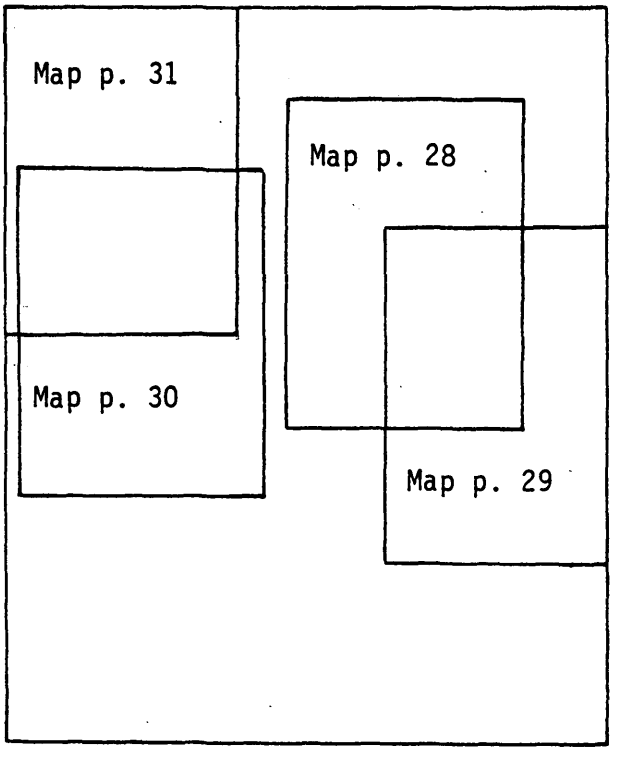
	Thickness Feet
Cliff House Sandstone (a local tongue):	
28. Sandstone, yellowish-gray to tan; same as unit 19 in Section K-16	>20.0
Menefee Formation (a local tongue):	
27. Coal, subvitreous	0.4
26. Shale, carbonaceous, dark-gray to black, resistant	11.3
25. Shale, gray; forms slope	11.1
24. Sandstone; yellowish-gray; forms ledge with bench on top	1.0
23. Shale, brown and sandstone, yellowish-gray, interbedded; forms a yellow slope	14.0
22. Sandstone, yellowish-gray; hard; forms ledge	2.1
21. Shale, carbonaceous, dark-gray; resistant; forms slight ledge	1.2
20. Shale, brown; forms slope	1.7
Cliff House Sandstone (a local tongue):	
19. Sandstone, light-brown to light-gray; forms ledge	31.0
Menefee Formation:	
18. Shale, carbonaceous; dark-gray; resistant; forms slight ledge	1.2
17. Coal, vitreous	0.9
16. Shale, carbonaceous, dark-gray; resistant; forms slight ledge	2.0
15. Shale, brown and gray; forms slope	8.8
14. Shale, carbonaceous, dark-gray; resistant	0.6
13. Coal, subvitreous	1.3
12. Shale, carbonaceous, dark-gray to black; resistant	1.5
11. Shale, brown and gray; forms slope	9.5
10. Shale, carbonaceous, dark-gray to black	1.2
9. Shale, brown and gray; forms slope	10.2
8. Sandstone, light-gray; forms slight ledge; bench on top	0.3

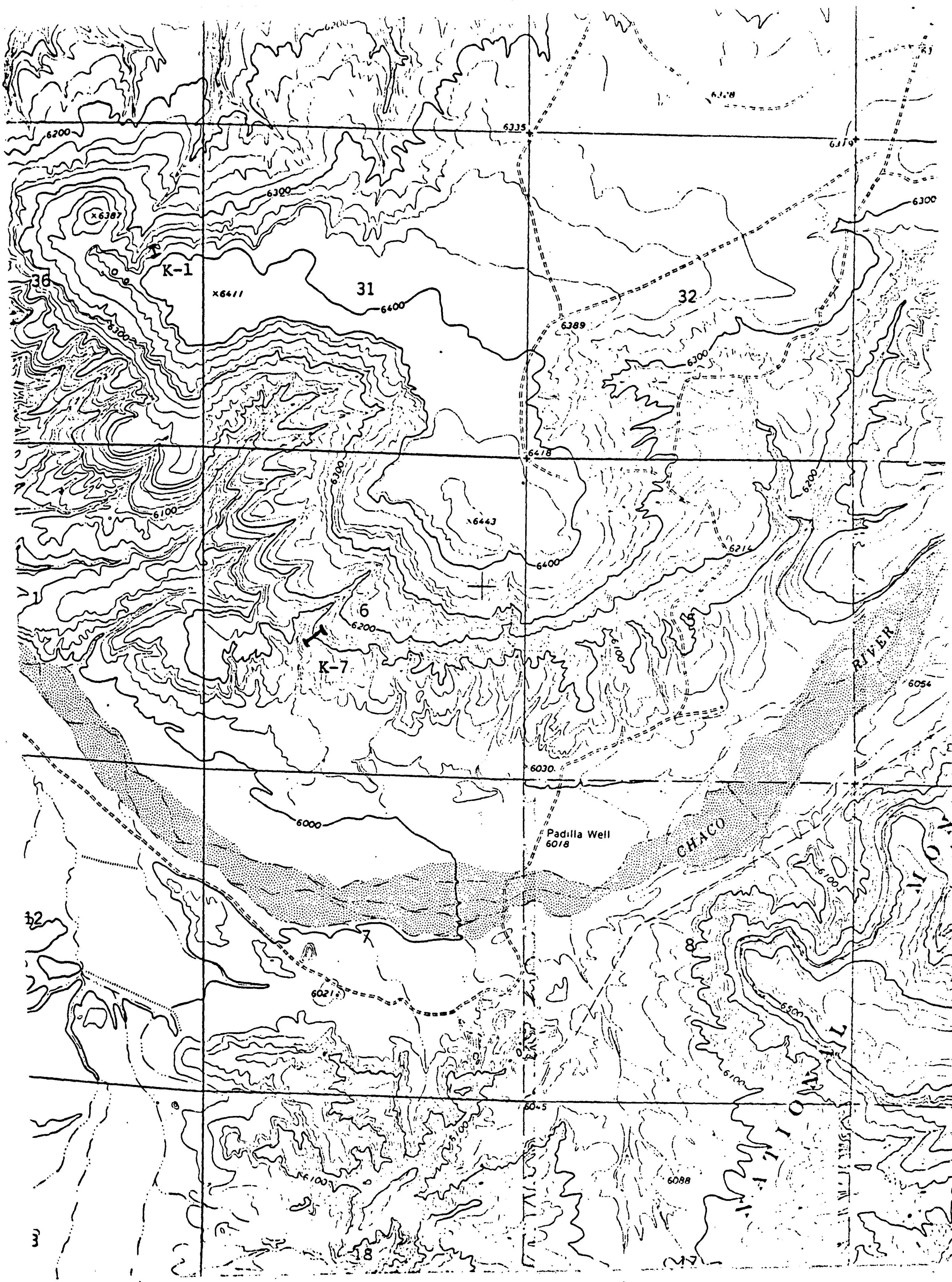
Section-19--continued

	Thickness Feet
Menefee Formation--continued:	
7. Shale, brown; forms slope----------	1.4
6. Shale, carbonaceous, dark-gray; resistant; forms slight ledge----------	1.8
5. Shale, brown; evenly bedded; forms slope----------	5.0
4. Sandstone, yellowish-gray; friable; contains some gray shale stringers----------	5.2
3. Shale, carbonaceous, dark-gray; resistant; forms slight ledge----------	3.0
2. Shale, gray and brown; forms slope----------	6.7
1. Sandstone, yellowish-gray; friable; base concealed in alluvium----------	10.0

APPENDIX B

Maps showing location of measured stratigraphic sections. Base from U.S. Geological Survey, Kin Klizhin Ruins quadrangle, 1966, 1:24,000. Approximate position of each location map within quadrangle is shown below:





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x6411
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6400
32
6389
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6100
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6
6200
K-7
6100
RIVER
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CHACO
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7
8
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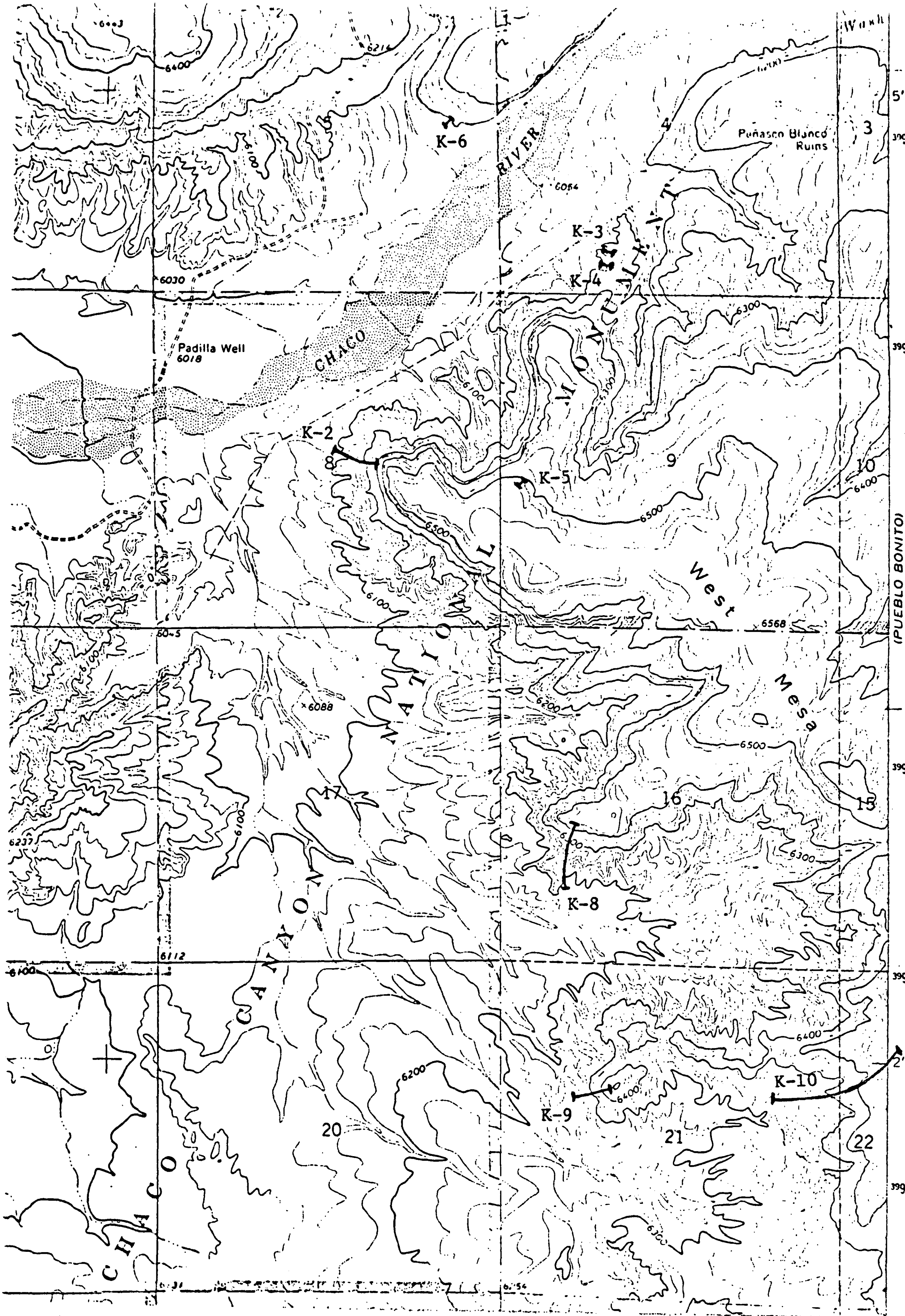
3
18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Peñasco Blanco Ruins
K-3
K-4
Padilla Well 6018
CHACO
K-2
K-5
NATIONAL MONUMENT
West Mesa
(PUEBLO BONITO) 4456 III SW
K-8
K-9
K-10
2'30"
CHACO CANYON
6400
6030
6300
6100
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6568
6088
6200
6112
6237
6054
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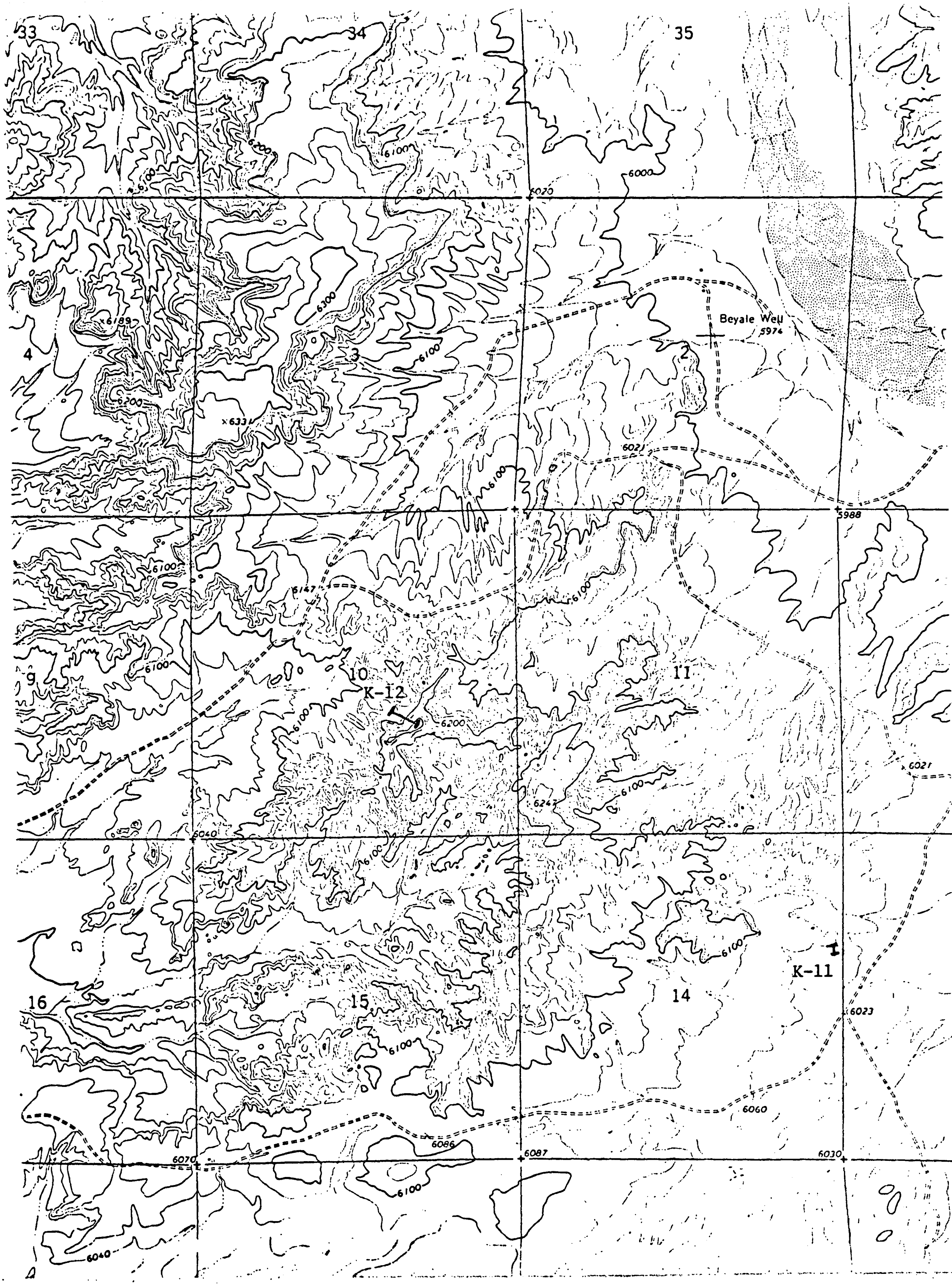
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5988
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10
K-12
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6100
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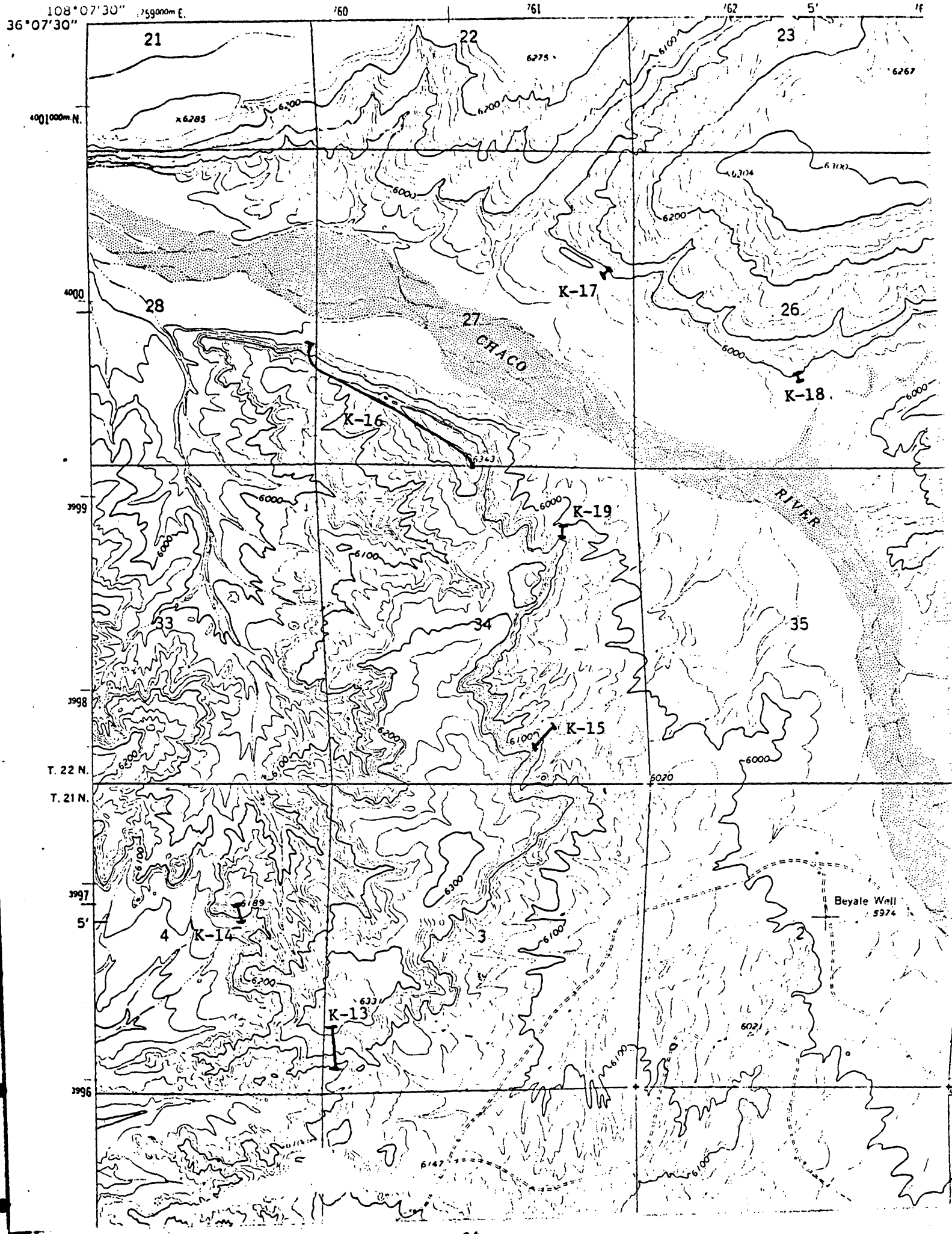
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760
761
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K-17
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6020
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Beyale Well
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