

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

Lithologic descriptions of selected intervals of Jurassic
rocks in southeastern Utah, northeastern Arizona, and
northwestern New Mexico

by
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Open-File Report 85-223

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

¹USGS Denver, Colorado

1985

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LITHOLOGIC DESCRIPTIONS OF SELECTED INTERVALS OF JURASSIC
ROCKS IN SOUTHEASTERN UTAH, NORTHEASTERN ARIZONA, AND
NORTHWESTERN NEW MEXICO

By Steven M. Condon

INTRODUCTION

This report contains descriptions of 18 measured sections of selected Jurassic rocks in the Four Corners area (fig. 1). Most of the sections were measured from the upper part of the Entrada Sandstone to the base of either the Salt Wash or Recapture Members of the Morrison Formation. In some sections, in the southern part of the area, all of the Morrison was measured and described up to the contact with the overlying Cretaceous Dakota Sandstone. Figure 2 shows the formations and members within this stratigraphic interval. The sections presented in this report are intended to aid other ongoing stratigraphic studies, and hopefully will have use in subsurface correlations of Jurassic units in the Four Corners area.

STRATIGRAPHY

The Carmel Formation is the oldest rock unit in southeastern Utah and northeastern Arizona that is considered to be entirely Jurassic in age. In the Four Corners area it forms ledges of resistant sandstone separated by siltstone slopes. The Carmel averages about 120 ft thick in southeastern Utah (O'Sullivan, 1965) and thins to the south and east of there. It isn't recognized in northwestern New Mexico (fig. 2). None of the Carmel is described in the measured sections included in this report.

The Entrada Sandstone overlies the Carmel in southeastern Utah and northeastern Arizona and is the lowermost Jurassic unit in northwestern New Mexico. In southeastern Utah and northeastern Arizona, the Entrada consists of a lower sandy, middle silty, and upper sandy lithofacies. In northwestern New Mexico, in most of the area of this report, the Entrada has been divided into a lower silty and upper sandy lithofacies. These lithofacies have been assigned various member names in different geographical areas. In the Carrizo Mountains area (fig. 1) the Entrada thins to as little as 40 ft (Strobell, 1956); however, it thickens to about 360 ft in the Lupton area (Harshbarger and others, 1957). A maximum of about 80 ft at the top of the Entrada was measured in the present study; most sections include just a few feet of the upper Entrada.

In the area of this report, the Wanakah Formation overlies the Entrada Sandstone. The Wanakah consists of three members, from oldest to youngest, the Todilto Limestone Member, the Beclabito Member, and the Horse Mesa Member (Condon and Huffman, in press).

The Todilto Limestone Member consists of gray, thinly bedded limestone and siltstone, and ranges from 0 to 20 ft thick in this area. It thins, as a result of nondeposition, onto the edges of the ancestral San Juan Basin. In this report, the Todilto is present in sections 7-12, Beclabito Dome to Navajo.

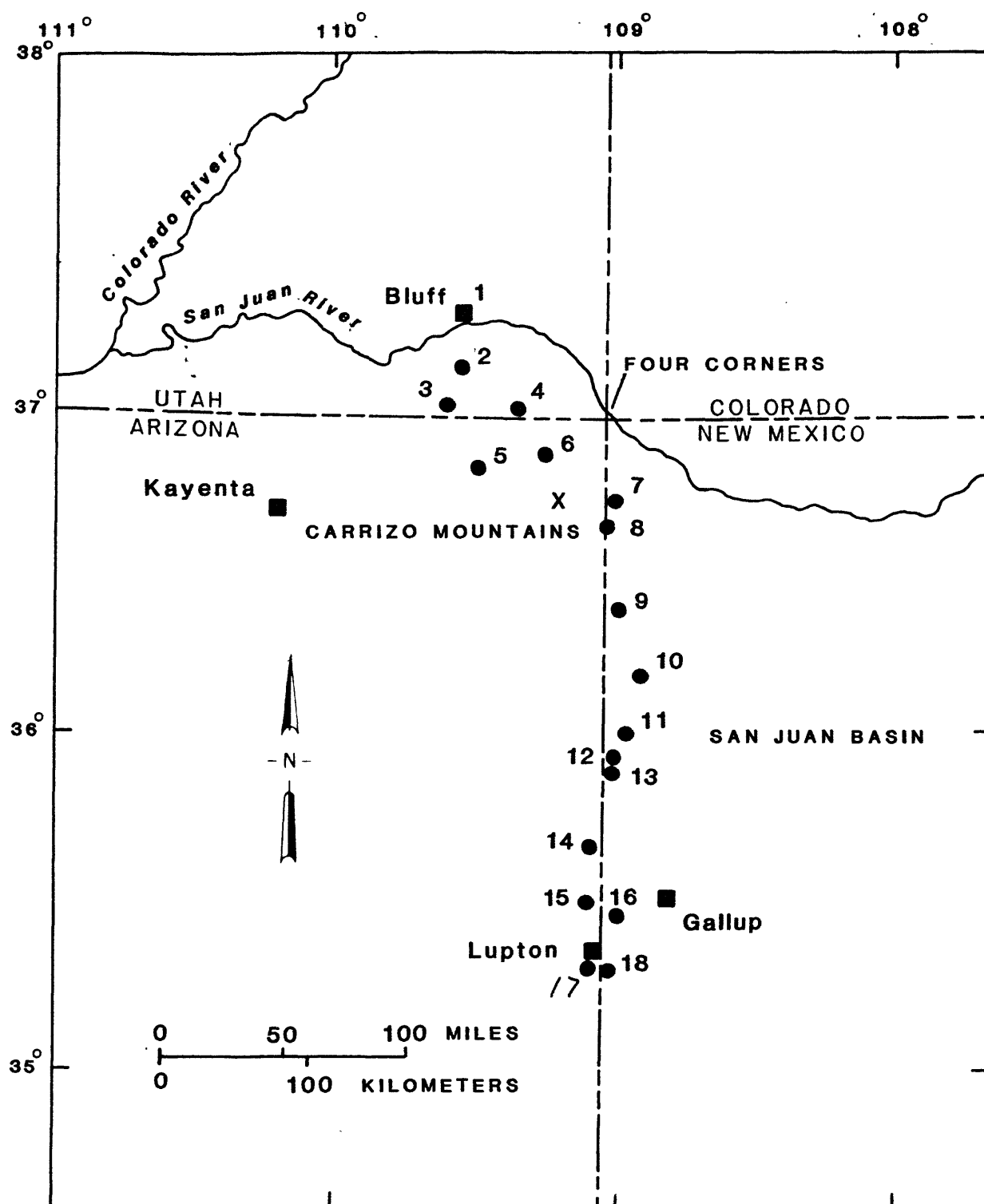


Figure 1. Index map of measured sections.

Bluff, Utah
 (section #1)

Beclabito, N. Mex.
 (section #7)

Lupton, Ariz.
 (sections #17, 18)

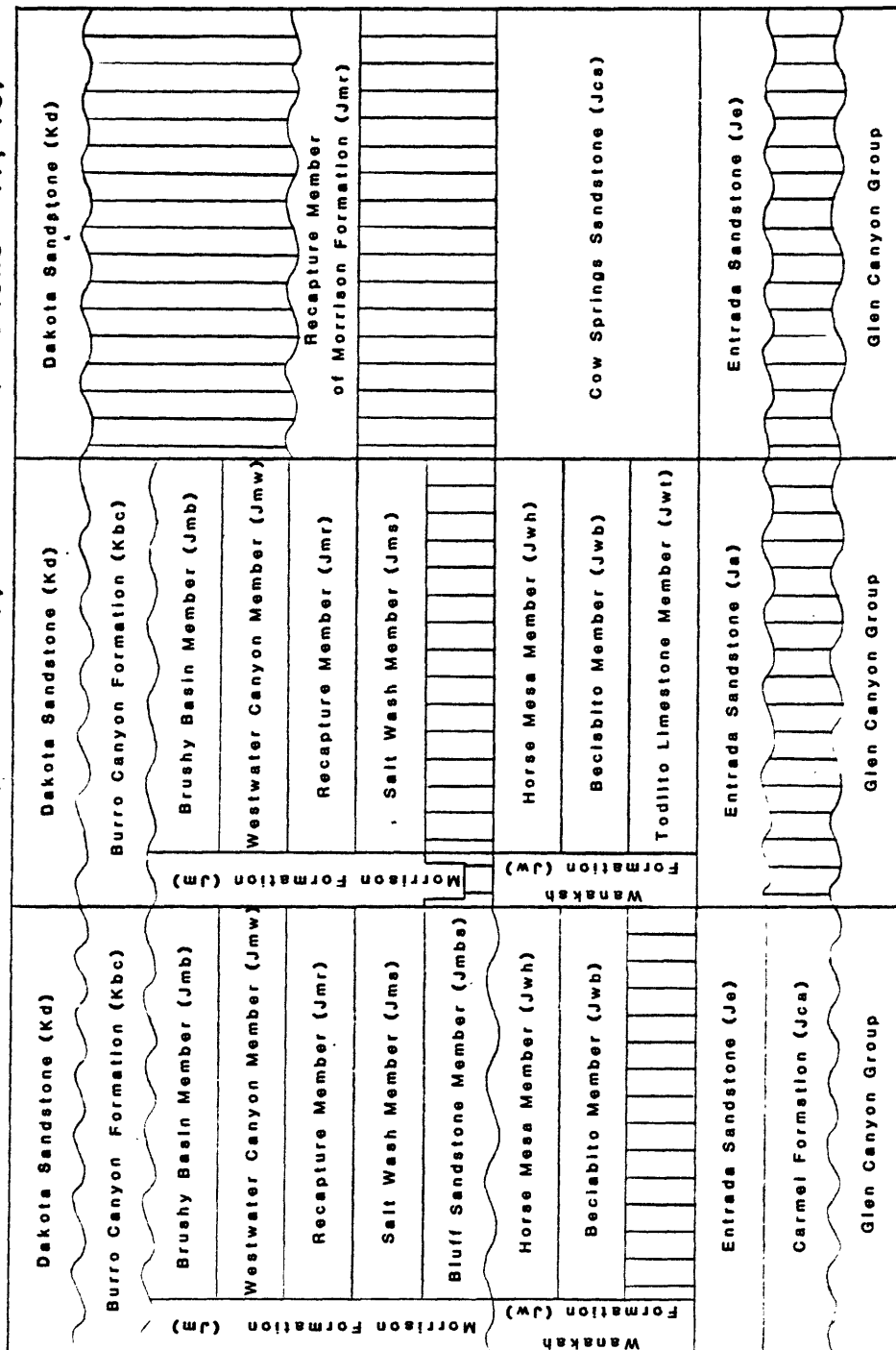


Figure 2. Correlation chart showing nomenclature of this report.

The Beclabito Member typically consists of a series of thin sandstone and sandy siltstone ledges separated by very thin siltstone and mudstone beds. A prominent sandy zone within the unit is the bed at Butler Wash (O'Sullivan, 1980). This bed is actually an interval of rock, consisting of a lower white sandstone, a middle part that is made up of thinly interbedded siltstone and sandstone, and an upper white sandstone. In the present report, the bed at Butler Wash has been correlated from southeastern Utah to northeastern Arizona and northwestern New Mexico. In southeastern Utah, the Beclabito ranges from about 170 to 200 ft in thickness. In northeastern Arizona and northwestern New Mexico, it is from 0 to about 175 ft thick. The Beclabito isn't recognized south of section no. 13 (Twin Buttes Wash).

The Horse Mesa Member is dominantly medium to coarse grained sandstone, and contains a few siltstone beds in its lower part. It was previously correlated with the Bluff Sandstone at Bluff, Utah (Strobell, 1956), but in the present report is considered to underlie the Bluff Sandstone Member of that area. The Bluff has now been reassigned as a member of the Morrison Formation (O'Sullivan, 1980). The Horse Mesa Member ranges in thickness from about 10 to 60 ft in northeastern Arizona and northwestern New Mexico, and 20-30 ft in southeastern Utah.

The Cow Springs Sandstone intertongues with and replaces the Beclabito and Horse Mesa Members of the Wanakah in a north-south direction along the Arizona-New Mexico state line. The Cow Springs consists of fine grained, well sorted sandstone, which is both crossbedded and flatbedded. It is present as thin tongues of light-colored, crossbedded sandstone within the Wanakah in the Todilto Park (no. 11), Navajo (no. 12), and Twin Buttes Wash (no. 13) sections and thickens southward. The thickness of the Cow Springs in the study area ranges from 0-283 ft.

The Morrison Formation overlies the Wanakah Formation in southeastern Utah, and overlies either the Wanakah or the Cow Springs Sandstone in northwestern New Mexico and northeastern Arizona. In southeastern Utah and northeastern Arizona the Morrison comprises five members: in ascending order, the Bluff Sandstone Member, the Salt Wash Member, the Recapture Member, the Westwater Canyon Member, and the Brushy Basin Member. In northwestern New Mexico, all of the members are present except the Bluff Sandstone Member.

The Bluff Sandstone Member consists of medium to coarse grained, crossbedded, and flatbedded sandstone. It ranges in thickness from 0 to nearly 350 ft (O'Sullivan, 1978). The Bluff thins northward, westward, and southward from Bluff, Utah; in the present report, thicknesses of 24-54 ft were measured.

The Salt Wash Member overlies either the Bluff Sandstone Member of the Morrison or the Wanakah Formation in the northern part of the study area (sections 1-9). The basal unit of the Salt Wash commonly consists of thin, tabular sandstone beds separated by siltstone or mudstone slopes. This unit is overlain by a coarsening-upward sequence of medium to thick tabular sandstones, and thin mudstone beds. No complete thicknesses of Salt Wash were measured in the present study.

In sections 10-18, the Recapture is the basal member of the Morrison. The Recapture is made up of sandstone, siltstone, and mudstone, with local limestone beds. Full thicknesses of the Recapture were measured in sections 14, 16, 17, and 18, and range from about 200 to 330 ft.

The Westwater Canyon Member overlies the Recapture and consists of medium to coarse grained sandstone and minor siltstone or mudstone beds. The Westwater Canyon was only measured at the Pipeline Road section (no. 14), where it is about 100 ft thick. It was removed by erosion prior to deposition of the Dakota Sandstone south of the Pipeline Road section.

The Brushy Basin Member overlies the Westwater Canyon Member. It consists of variegated claystone and mudstone with minor lenticular sandstone and limestone beds. None of the Brushy Basin was measured or described in the present study.

In southeastern Utah and part of northwestern New Mexico, the Cretaceous Burro Canyon Formation overlies the Morrison Formation. The Burro Canyon is not recognized in Arizona or in much of northwestern New Mexico. In areas where it is absent, the Cretaceous Dakota Sandstone overlies the Morrison Formation. Neither the Burro Canyon or Dakota Sandstone were measured or described as part of the present study.

LOCATION

The sections were measured from Bluff, in southeastern Utah, southward to Lupton, Arizona (fig. 1). Outcrops of Jurassic rocks are somewhat scattered in southeastern Utah and northeastern Arizona; however, exposures there are generally good, and units could be traced from one section to another with confidence. Sections 7-11 in New Mexico are well-exposed but separated by cover, particularly between sections 10 and 11. Sections 12-18 are along a line of nearly continuous cliffs that define the western edge of the San Juan Basin.

METHODS

Field data were recorded on forms intended for outcrop or core studies that are described in detail by Reynolds and others (1975). Appendix A explains symbols and abbreviations used on the forms. Note that there are continuous lines that indicate the visual porosity estimate and dominant grain size on the forms. These lines approximate the spontaneous-potential and resistivity curves on a standard geophysical log. The forms were designed this way to ease comparison between outcrop and subsurface data.

Wherever possible, measurements were made with a 5 ft Jacob staff and Abney level. A tape measure was used in areas where cliffs made use of the Jacob staff impractical. Two sections (Gothic Wash, no. 2, and Twin Buttes Wash, no. 13) were measured, in part, over long, gentle dipslopes. Thicknesses measured in those areas are possibly subject to error. The strata at the Toadlena section, no. 10, dip eastward at approximately 75°, and there may be some tectonic thinning of the units in that section.

Many thanks go to John McDonnell, Paul Hildebrandt, and Carl Harris, who assisted in measuring these sections. The discerning reader will note small stylistic differences between sections. These are due, in large part, to differences between field assistants.

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- Goddard, E. N., Trask, P. D., De Ford, R. K., Rove, O. N., Singewald, J. T., Jr., and Overbeck, R. M., 1948, Rock-color chart: The Geological Society of America.
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APPENDIX A

Explanation of section forms

The section forms in this report are divided into vertical columns that each contain different types of information. Each column will be discussed briefly below.

Depth / alt. and formation tops. In this report this column is used to indicate thicknesses of the units in feet.

Shows. Because these forms are designed for subsurface, as well as surface sections, a column for oil shows is included. This column was not used in this report.

Fractures. The fractures column was also included on these forms for use in core studies. In this report this column is used to indicate stratigraphic units. (See figure 2 for the symbols used for formations and members.)

C.P.S. C.P.S. refers to counts-per-second of a hand-held scintillometer. Readings of relative radioactivity were taken for some of the sections. The abbreviation "Bk" on some of the forms refers to the background readings.

Visual porosity estimate. This column is a continuous line graph representing an estimate of the porosity of the unit measured. Estimates were obtained by placing a few drops of water or dilute HCl on the rock.

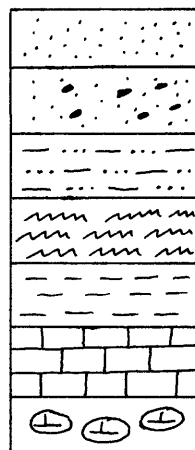
Core. This indicates the number of the core run for subsurface studies. It was not used in the present report.

Rock type. The rock type column contains a weathering profile of the outcrop, a lithologic symbol for rock type, drawings of sedimentary structures within the units, and arrows and numbers that designate the position of samples taken. Small strike and dip symbols next to some intervals indicate the presence of calcareous zones.

Lithology

Sandstone
Conglomeratic sandstone
Siltstone
Mudstone
Claystone
Limestone
Limestone clasts or nodules

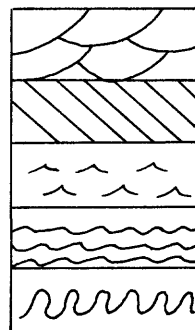
Symbol



Sedimentary structures

Trough crossbeds
Tabular-planar crossbeds
Ripples (current or oscillation)
Adhesion ripples
Contorted bedding

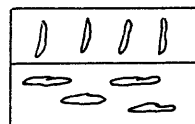
Symbol



Miscellaneous

Burrows
Vertical
Horizontal

Symbol



Footnotes. Used to indicate location of samples collected.

Color. Colors were estimated by a comparison with the GSA Rock-color chart (Goddard and others, 1948). Where possible, colors were estimated from fresh, dry outcrops.

Dominant grain size. The dominant grain size of rock units was estimated by comparing them to standard grain size charts. Class divisions correspond to the phi scale. Dots to the left or right of the solid line indicate variations from the norm.

Bedding. Bedding refers to set thickness of sedimentary units. Abbreviations are as follows: VTK - very thick; TK - thick; M, MED, or AV - medium; TN - thin; VTN - very thin; LAM - laminated; MASS - massive. Combinations of terms indicates a range of bedding thicknesses.

Sedimentary structures. This column indicates the type of sedimentary structure that is shown graphically in the rock type column. Abbreviations of sedimentary structures are as follows: CLL - trough crossbeds (curved, parallel laminations); SM, LO & TR. - small scale, low angle trough crossbeds (there are several variations of this notation, depending on the scale and angle of crossbedding); TAB. PLANAR - tabular-planar crossbeds; DWLL - current or oscillation ripples (discontinuous, wavy, nonparallel laminations); WLL - adhesion ripples (wavy, nonparallel laminations); ELL - horizontal laminations (even, parallel laminations); STRLESS - structureless.

Biologic constituents. This column indicates the presence of organic material, burrowing, and bioturbation.

Sorting and roundness. Commonly used abbreviations for sorting are as follows: VWS - very well sorted; WS - well sorted; MWS - moderately well sorted; M or MOD - moderately sorted; FS - fair sorting; PS - poorly sorted. Abbreviations for roundness include: A - angular; SA - subangular; SR - subrounded; R - rounded.

Cement. This column was used to indicate the presence of calcite cement. Abbreviations used include: V. CAL - very calcareous; M. CAL or MOD. CAL - moderately calcareous; SL. CAL - slightly calcareous; NON CAL or N. CAL - non-calcareous.

Percent feldspar. Estimated percent feldspar, usually potassium feldspar, in the unit.

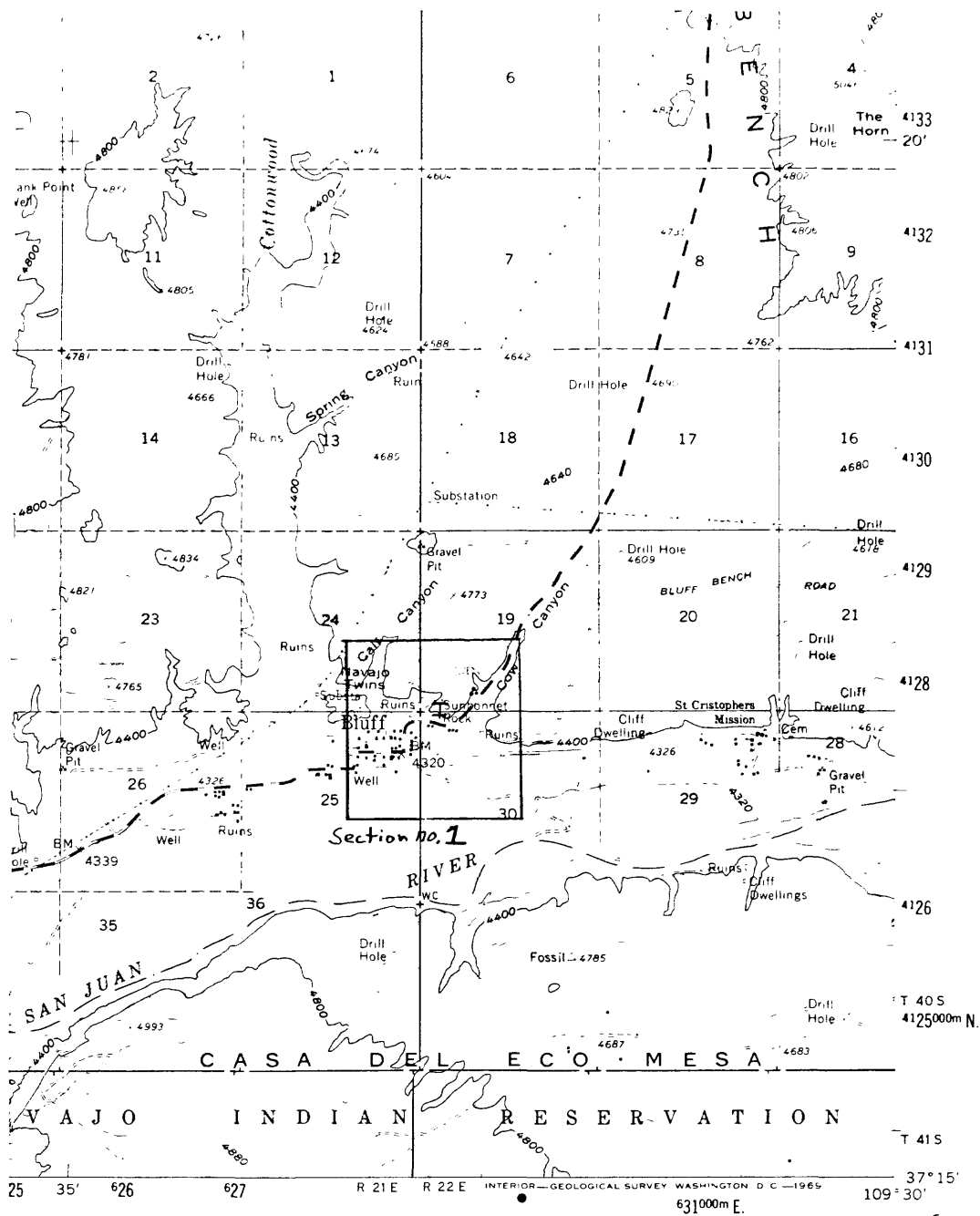
Accessory minerals or fragments. Colors of unidentified accessory minerals are in this column. Abbreviations for colors are: BK or BLK - black; R or RD - red; OR - orange; GRN - green; GY - gray; WT - white. In some sections an attempt was made to estimate the percentage of accessory minerals.

Description. This is essentially a "comments" section. It contains information not covered on the rest of the form.

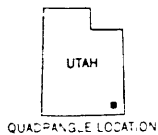
Inferred environment of deposition. Possible environments of deposition are noted in this section. These interpretations are preliminary, and two or more possibilities are often listed.

Transport direction. Where possible, estimates of the direction of sediment transport were made. Most of these estimates were taken from axes of trough crossbeds.

APPENDIX B
Measured sections



4 MILES
21,000 FEET
METERS



ROAD CLASSIFICATION
Medium-duty ——— Light-duty ———
Unimproved dirt =====
○ State Route

The west half of this area also covered by 7 1/2 minute 1:24,000 scale maps Bluff NW 1962 and Bluff SW 1962

BLUFF, UTAH
N3715—W10930/15

1962

AMS 4058 I-SERIES V797

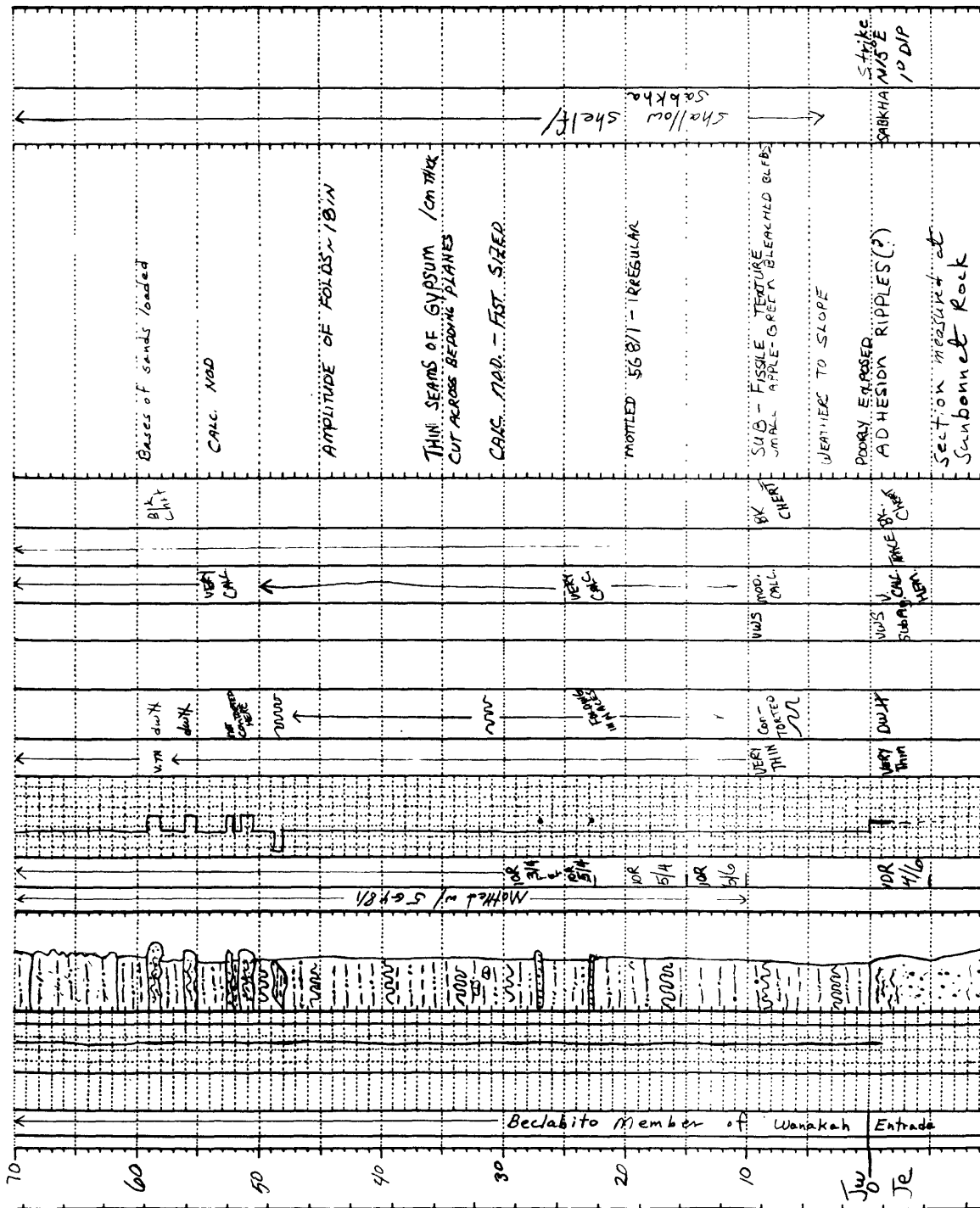
J. C. 20242

Scale 1:62,500

Figure 3. Location of measured section no. 1.

LOCATION 1. BLUFF NW 1/4, NW 1/4 Sec. 30, SW 1/4, SW 1/4 Sec. 19, Sec. NW 1/4, SE 1/4 19. T. 40. S. R. 22. E.

STATE UTAH COUNTY San Juan
U.S.G.S. CORE LIBRARY NUMBER 7/83 API WELL NUMBER COMMON / HARRIS



API WELL NUMBER



API WELL NUMBER

15

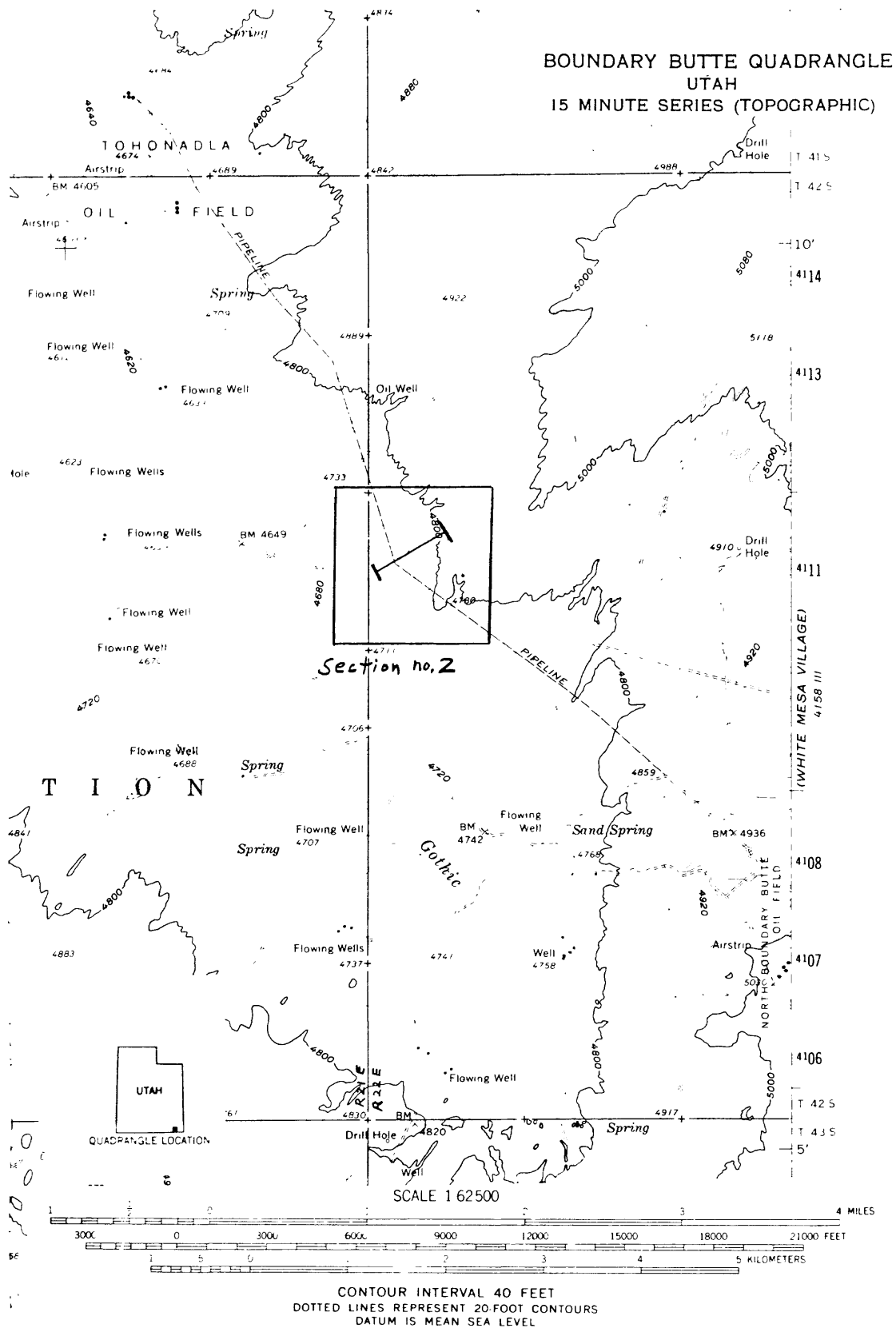
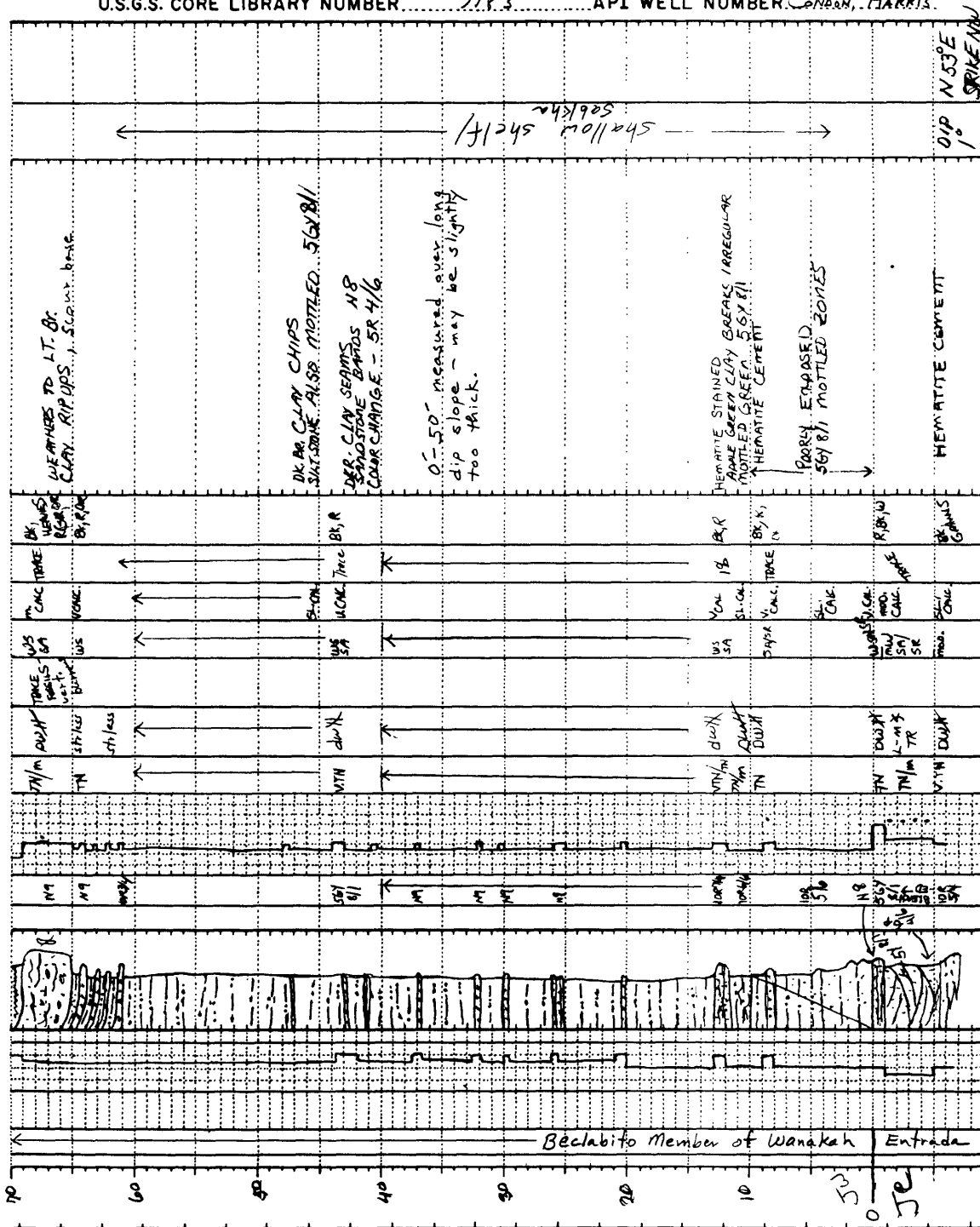
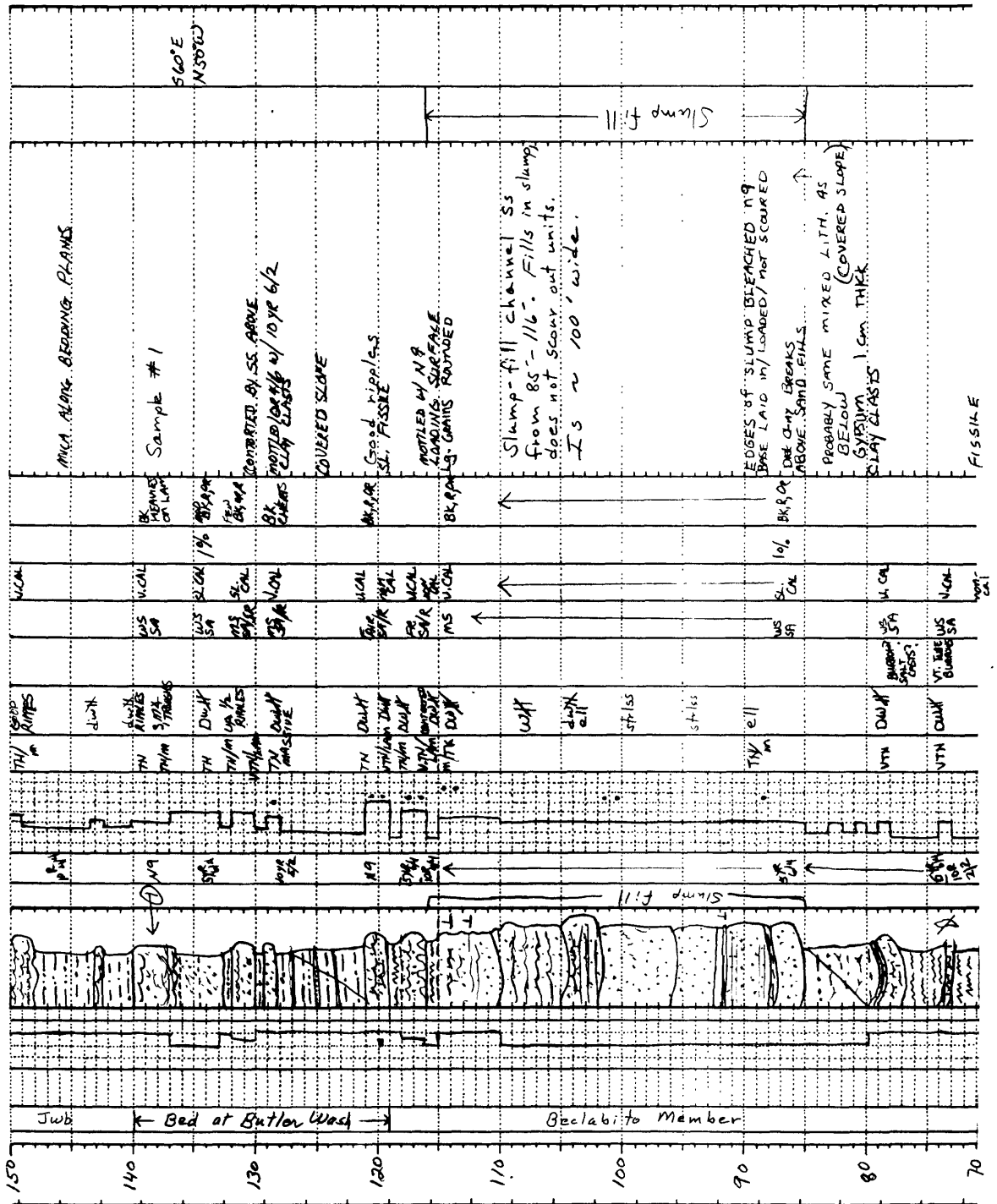


Figure 4. Location of measured section no. 2.

LOCATION ²GOthic WASH. Sec. 18 ^{S 1/2, NW 1/4} T. 42 S. R. 22 E (estimated)
STATE UTAH COUNTY San Juan
U.S.G.S. CORE LIBRARY NUMBER 7193 API WELL NUMBER CONARN, HARRIS



LOCATION GOthic WASH Sec. 18 T. 42 S. R. 22 E.
 STATE UTAH COUNTY _____
 U.S.G.S. CORE LIBRARY NUMBER _____ API WELL NUMBER _____



LOCATION GOTHIC WASH Sec. 18 T. 42 S. R. 22 E.
 STATE UTAH COUNTY _____
 U.S.G.S. CORE LIBRARY NUMBER _____ API WELL NUMBER _____

DEPTH AND FORMATION TOPS	SHOES	FRACTURES (Type, angle)	C.P.S.	Visual Porosity	Core	ROCK TYPE	FOOTNOTES	COLOR	CLAY DOMINANT	GRAIN SIZE	BEDDING (as observed)	SEDIMENTARY STRUCTURES	BIOLOGIC CONSTITUENTS	MINERAL HUMATE	SOFTNESS	BOUNDING	CEMENT	PERCENT	ACCESSORY MINERALS OR FRAGMENTS	DESCRIPTION	INFERRED ENVIRONMENT OF DEPOSITION	TRANSPORT DIRECTION	
210	Jmb is					Jmb is incomplete																	
200	Jwb																						
190	Jwb (Bealabito Member of Wanakah)																						
180																							
170																							
160																							

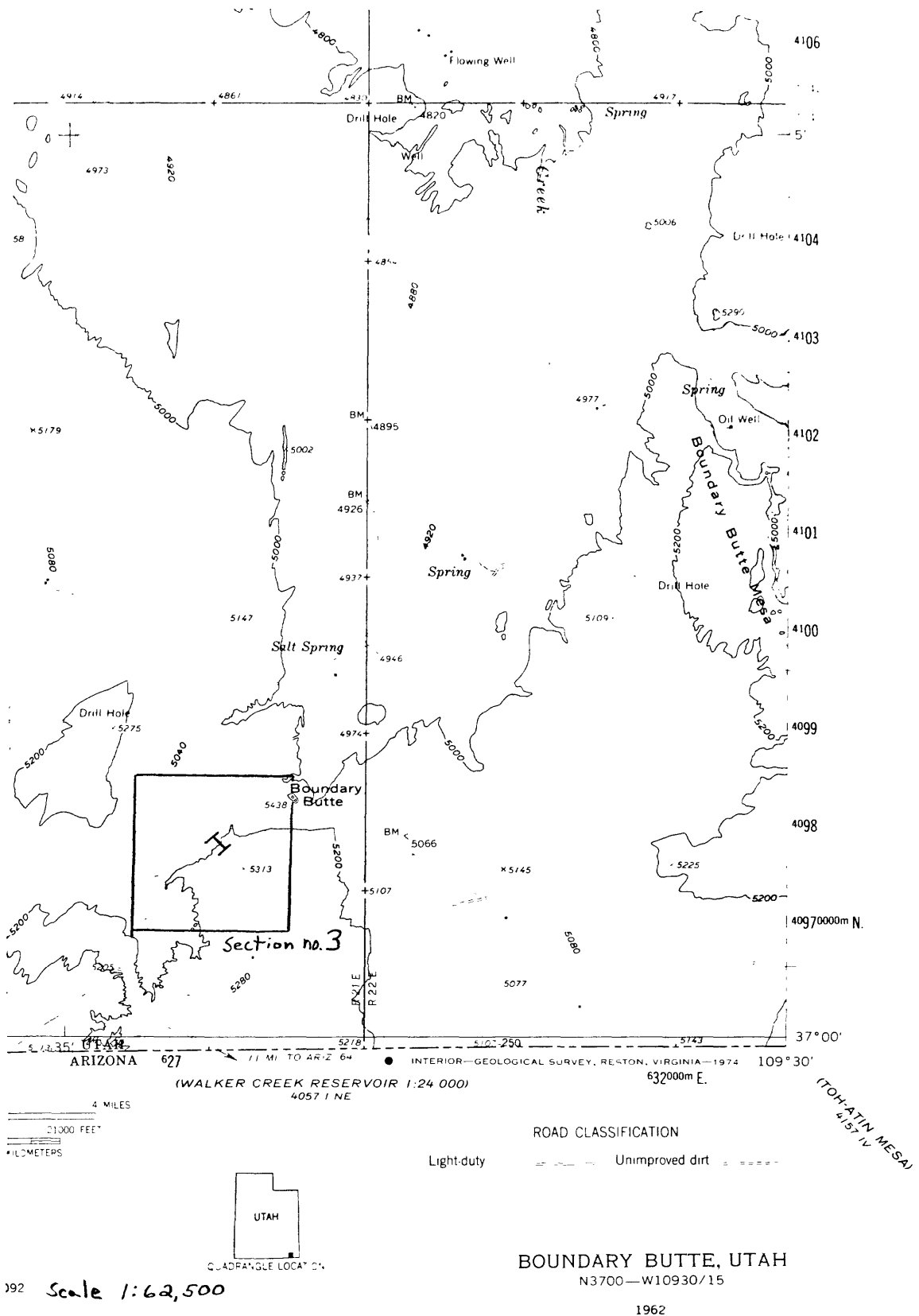


Figure 5. Location of measured section no. 3.

Shallow shelf / sabkha

CONTINUED

FRAME GR. REDUCED SPOTS (1mm ACROSS)

FE CONC. / UCAIC. / FST-SIZED

SOME CONTINUING OF BEDDING

1% BLK. OF STAINED GR. GRAINS

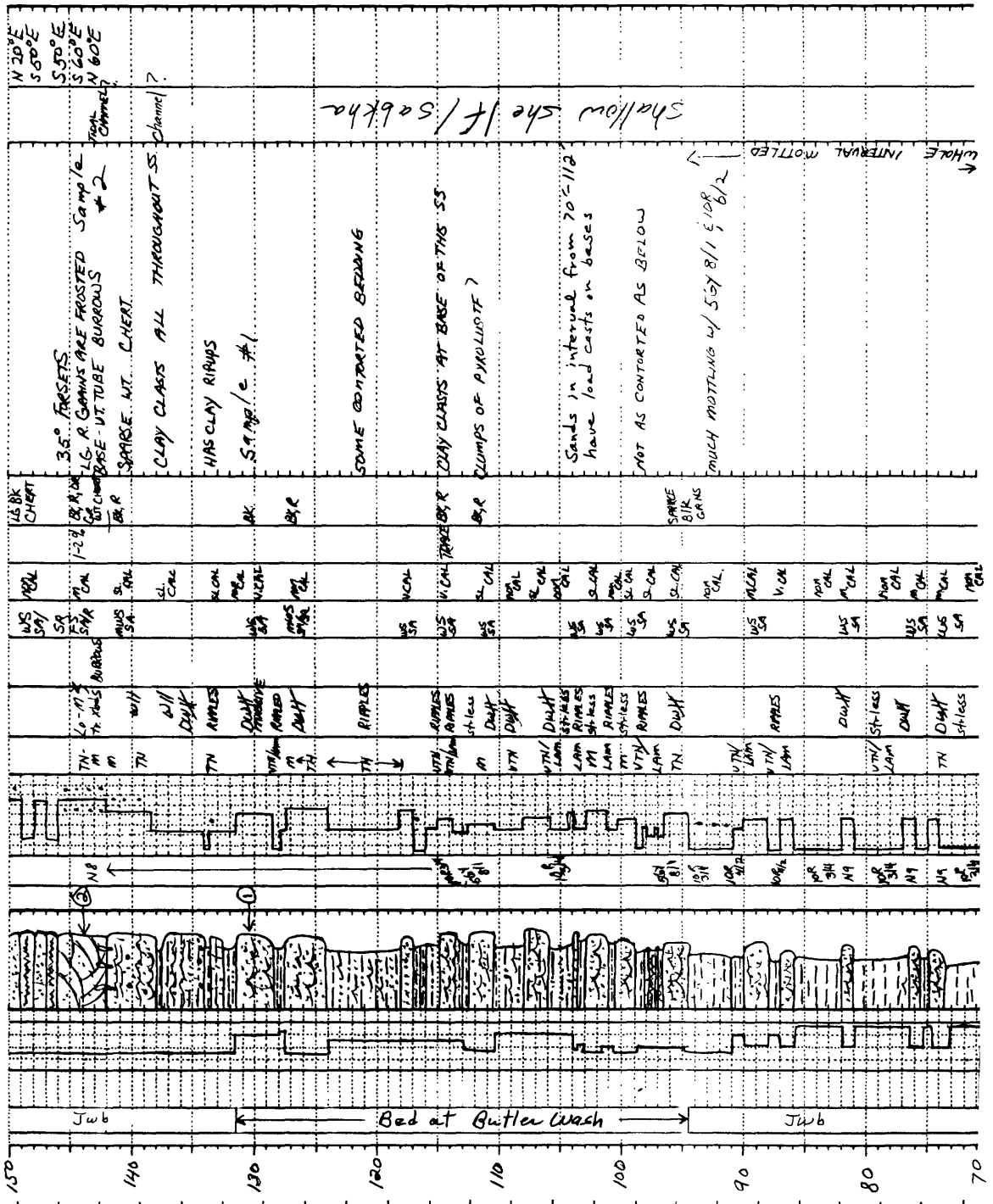
FEW CLAY SPLITS

70 60 50 40 30 20 10 0

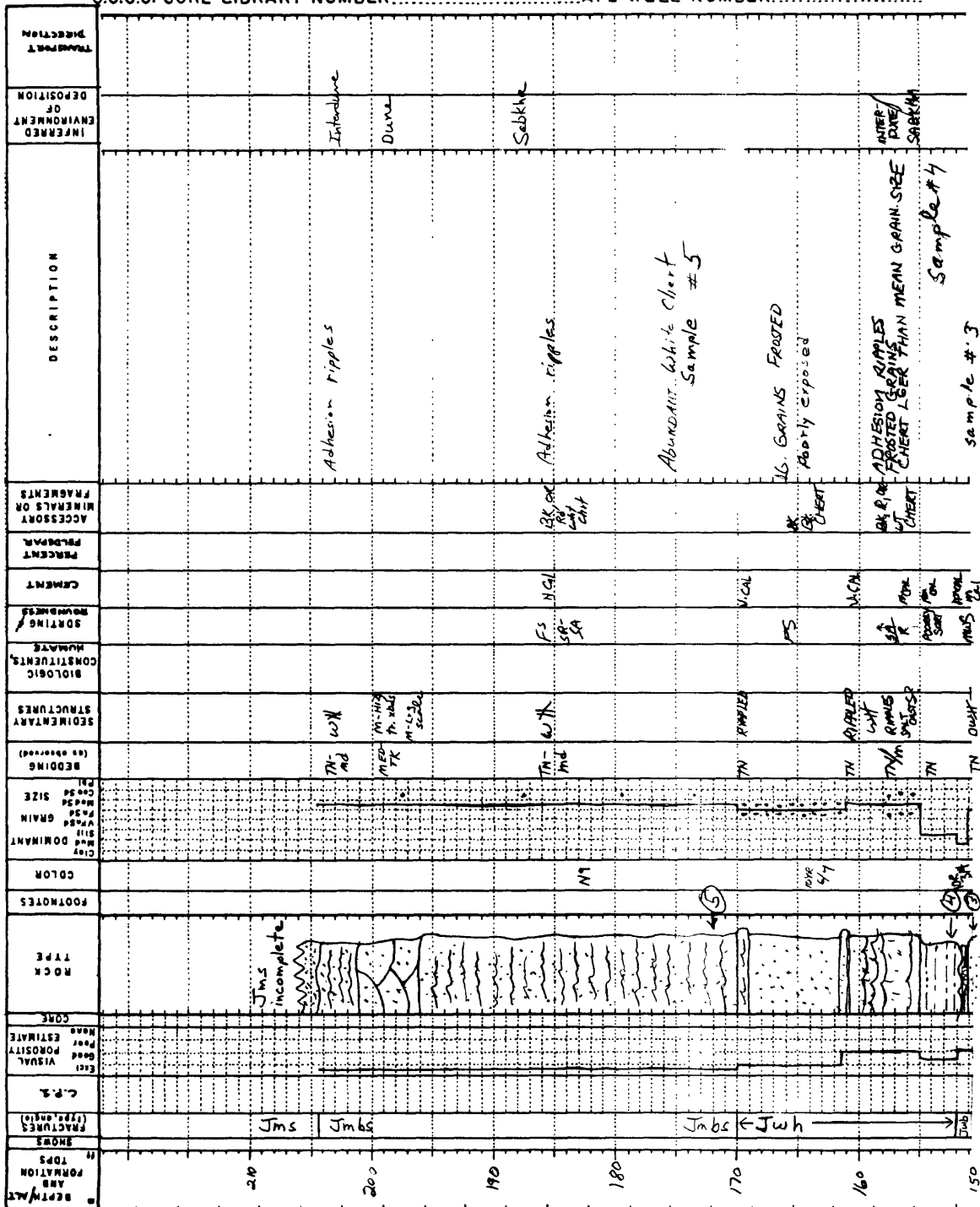
Beclabito Member

Jw Je

LOCATION Boundary Butte Sec. 25 T. 43 S. R. 21 E
 STATE UTAH COUNTY San Juan
 U.S.G.S. CORE LIBRARY NUMBER _____ API WELL NUMBER _____



LOCATION BOUNDARY BUTTE Sec. 25 T. 43 S. R. 21 E.
 STATE UTAH COUNTY San Juan
 U.S.G.S. CORE LIBRARY NUMBER _____ API WELL NUMBER _____



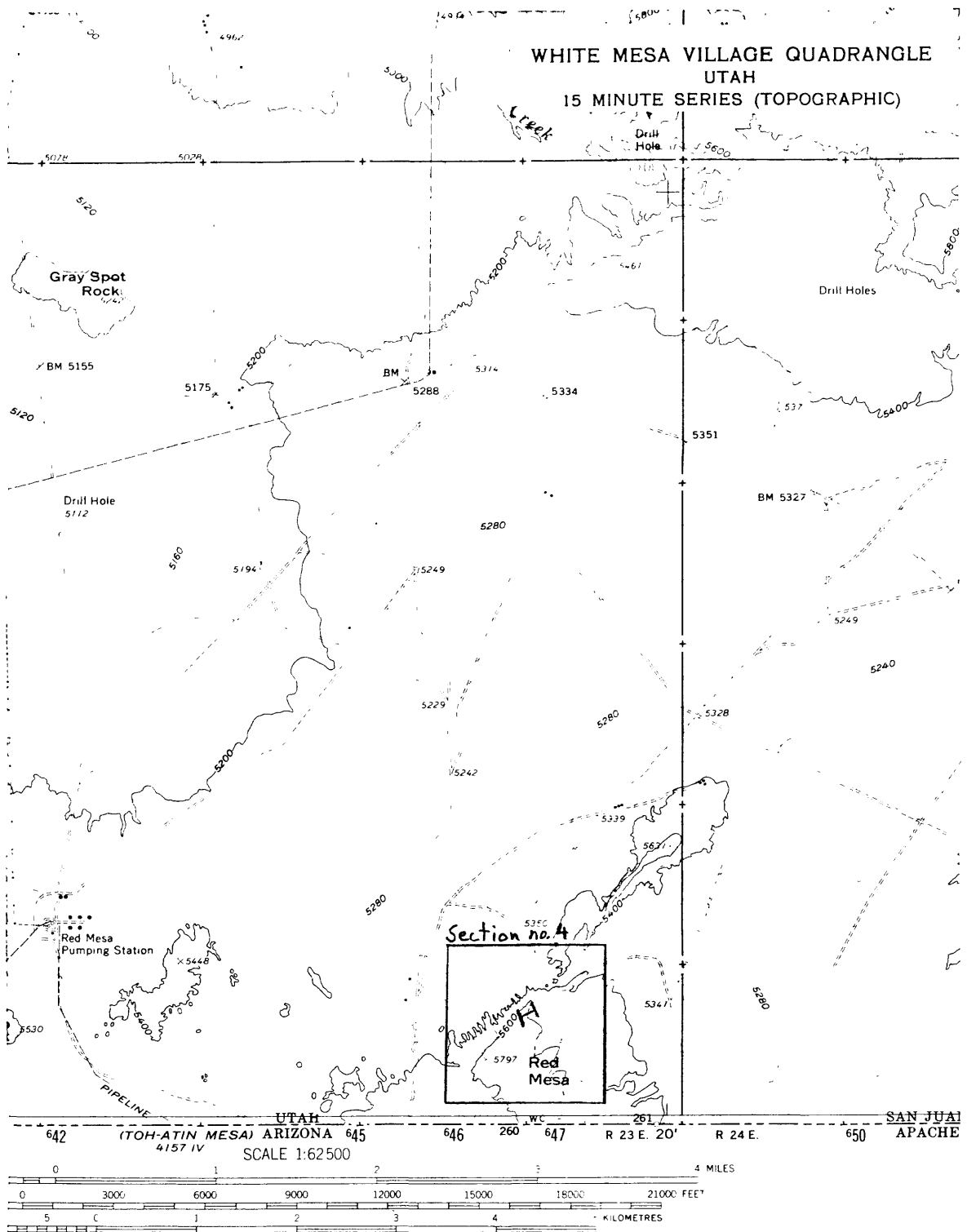
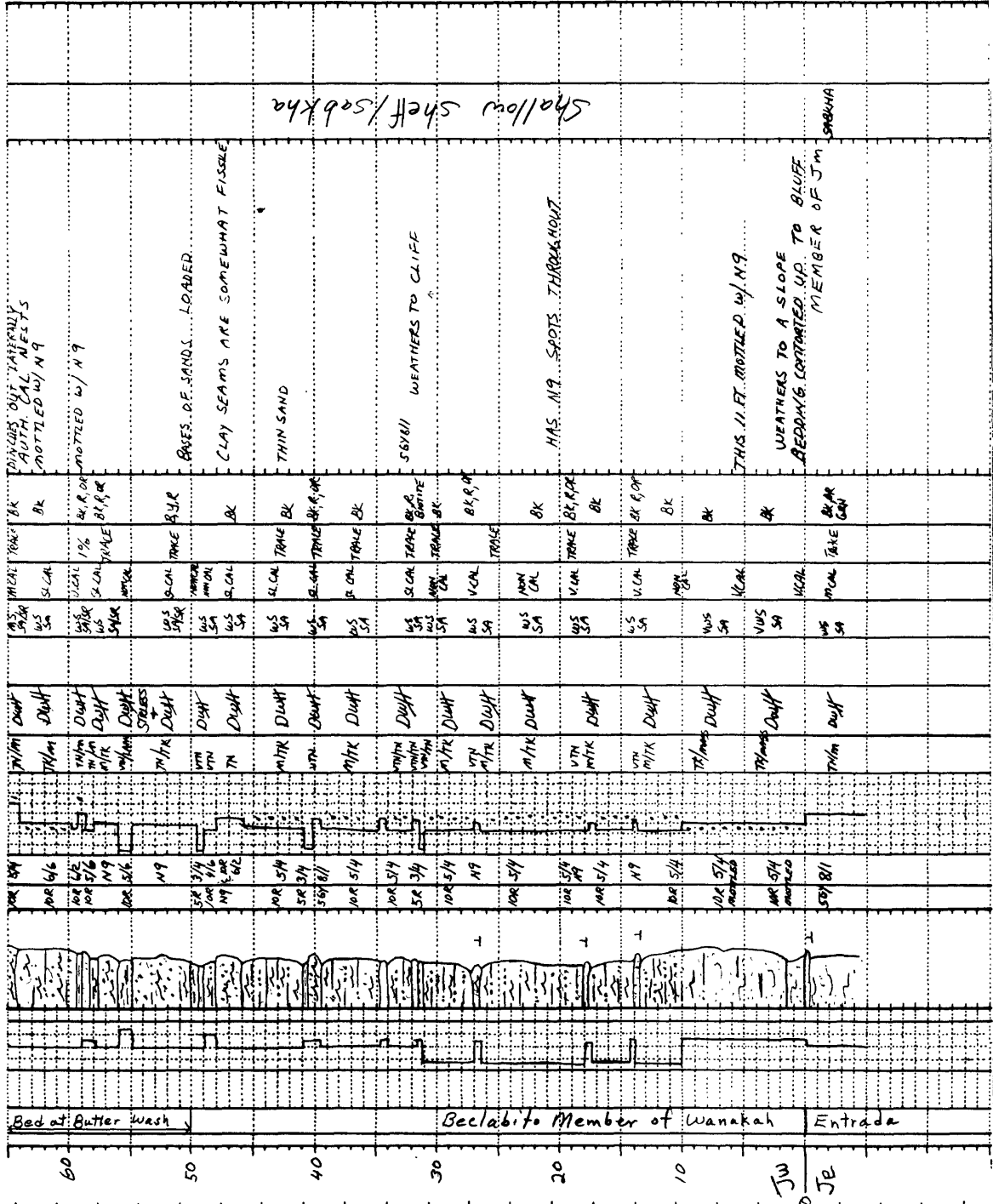
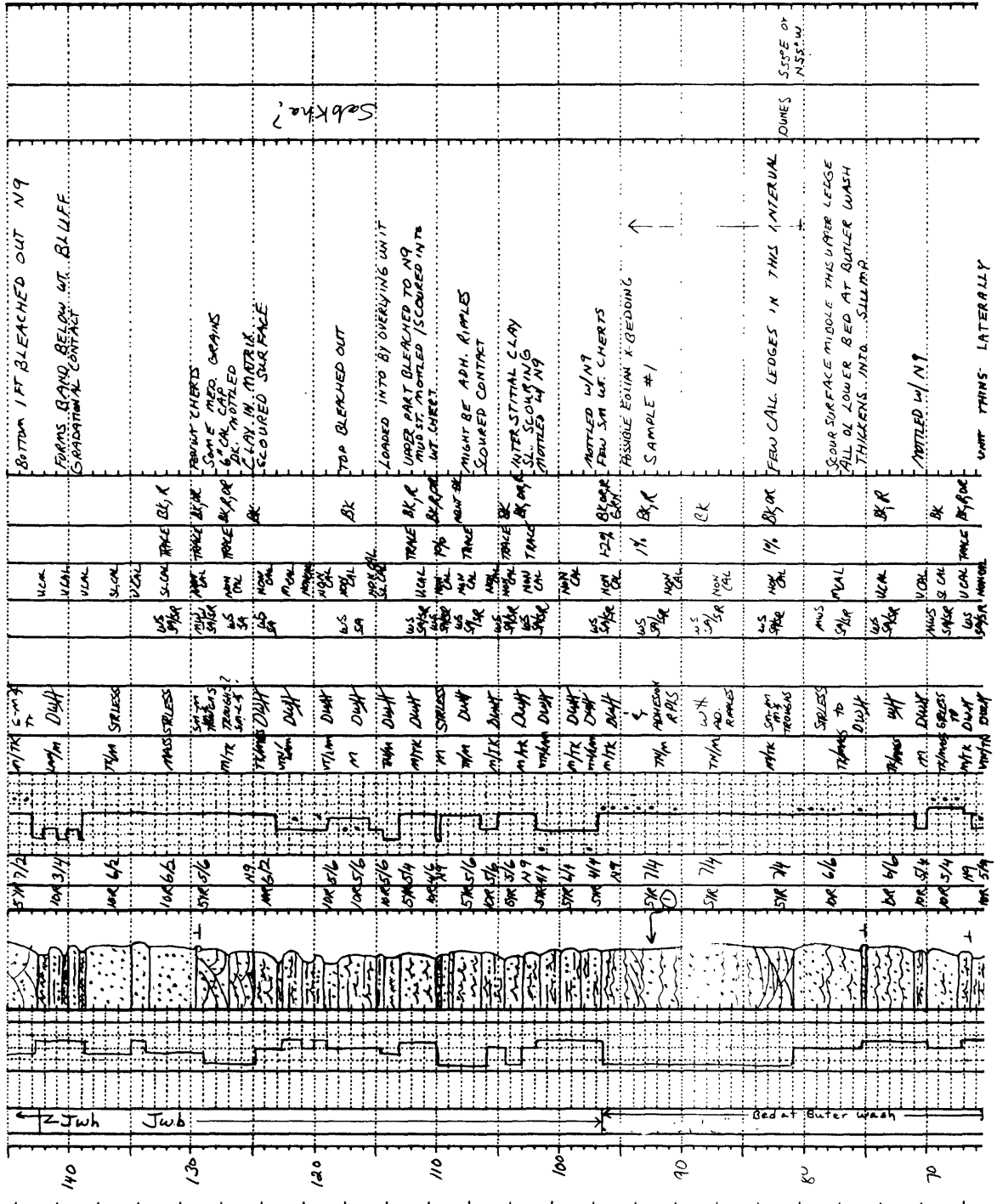


Figure 6. Location of measured section no. 4.

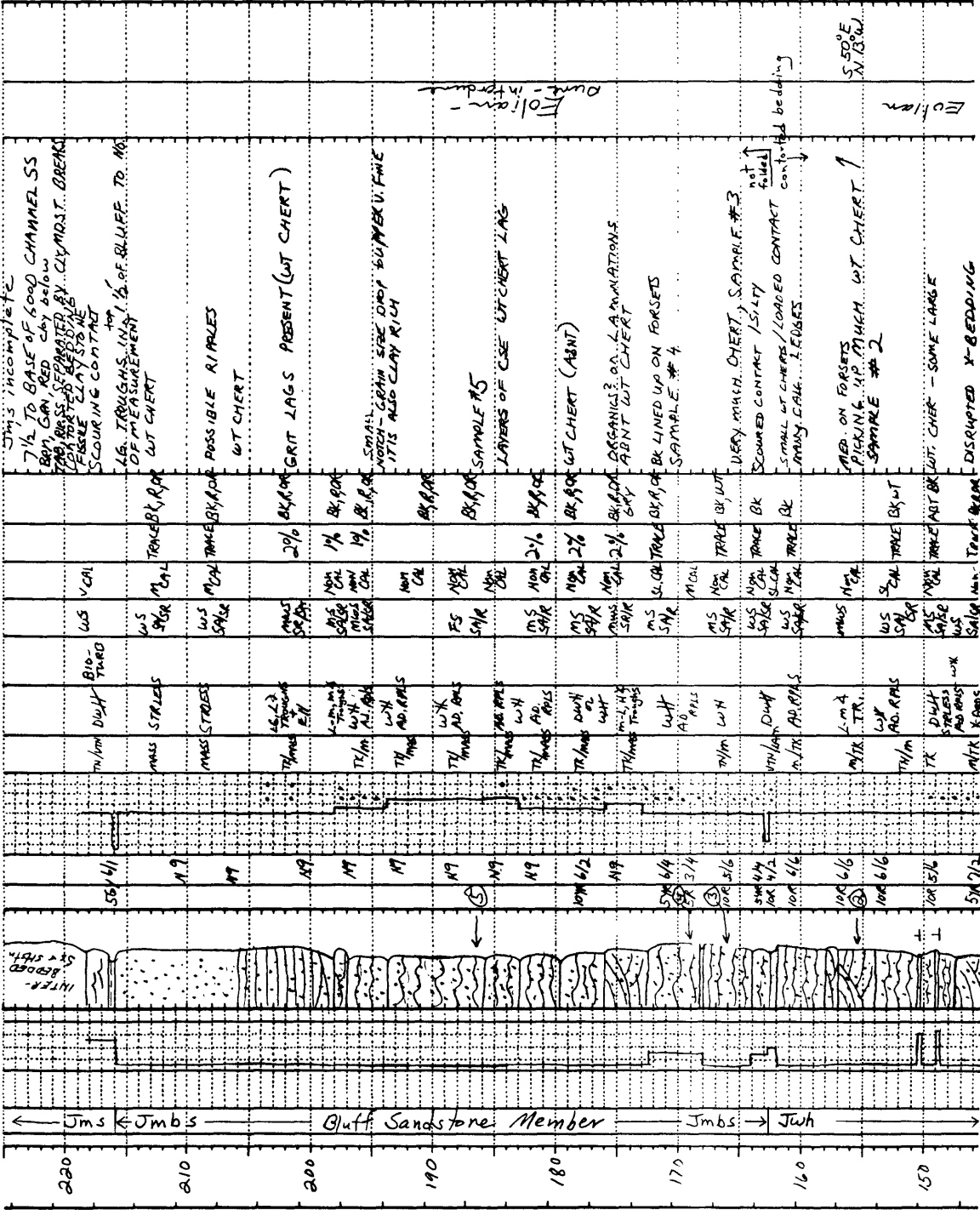
LOCATION ⁴ RED MESA Sec. ^{W 1/2, NW 1/4} 36 T. 42 S R. 23 E
 STATE UTAH COUNTY San Juan
 U.S.G.S. CORE LIBRARY NUMBER 8183 API WELL NUMBER CONDON, HARRIS



LOCATION RED MESA Sec. 36 T. 43.5 R. 23E
 STATE Utah COUNTY San Juan
 U.S.G.S. CORE LIBRARY NUMBER _____ API WELL NUMBER _____



U.S.G.S. CORE LIBRARY NUMBER.....API WELL NUMBER



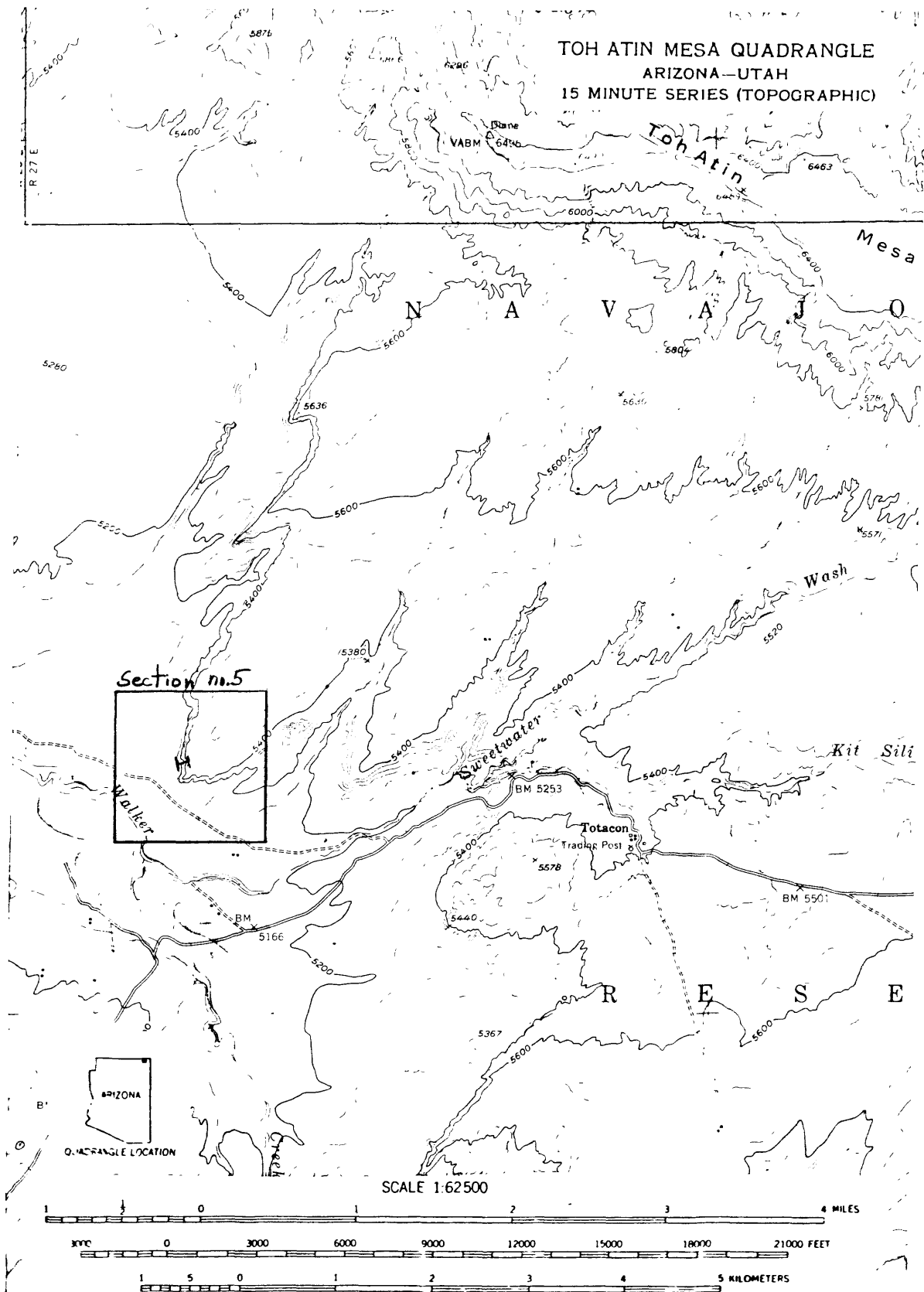
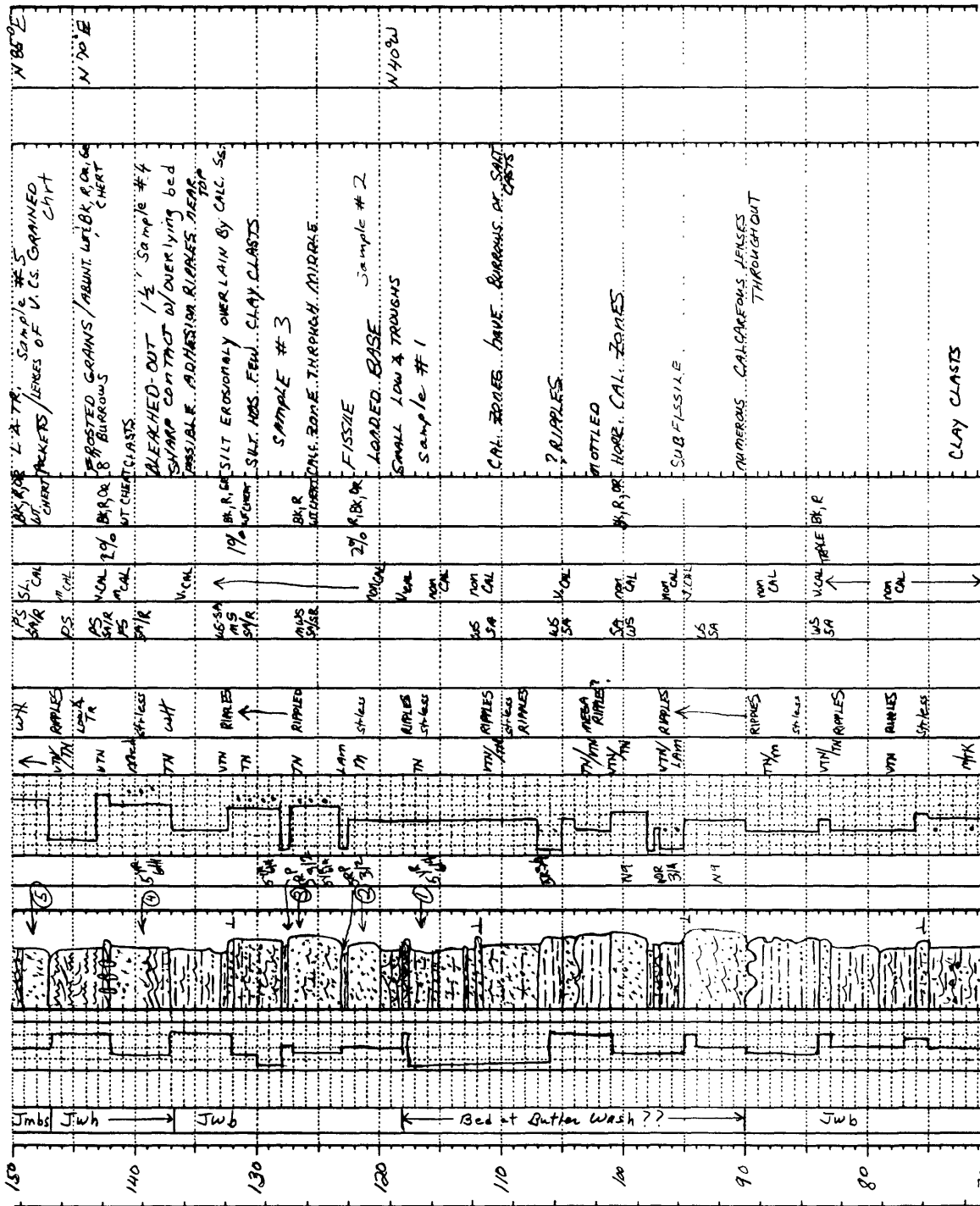


Figure 7. Location of measured section no. 5.

[illegible]

⑧



U.S.G.S. CORE LIBRARY NUMBER.....API WELL NUMBER

[illegible]

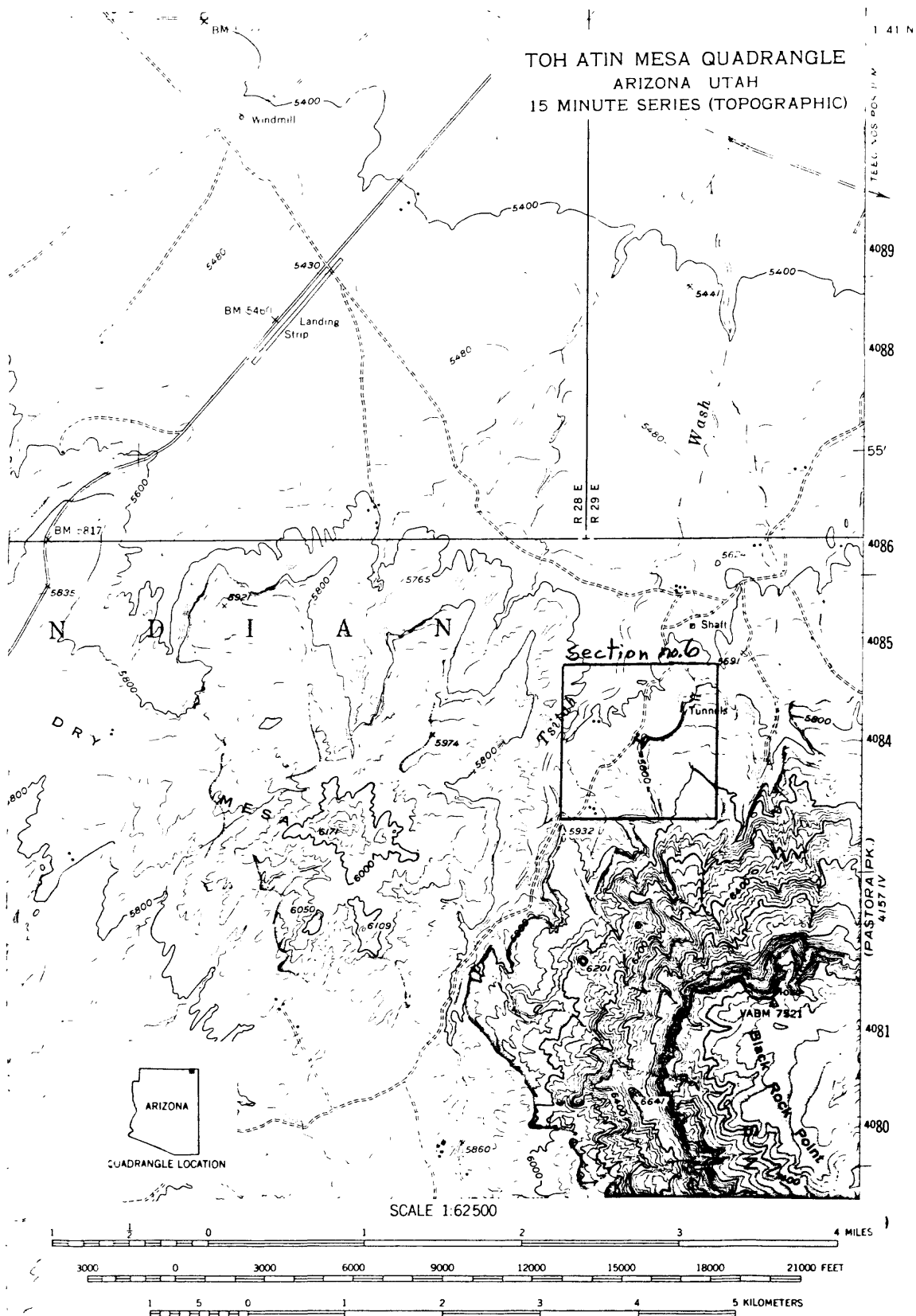
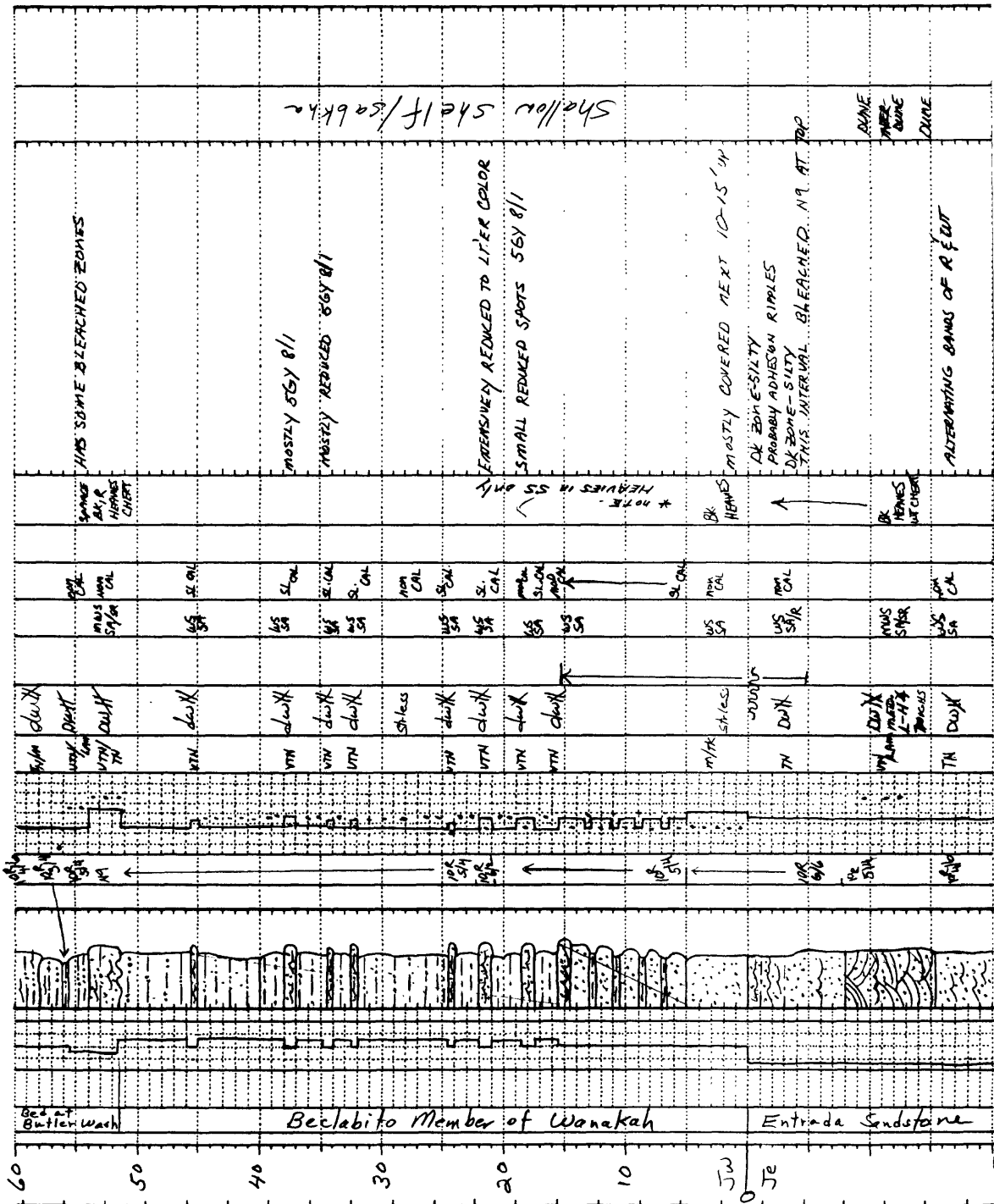
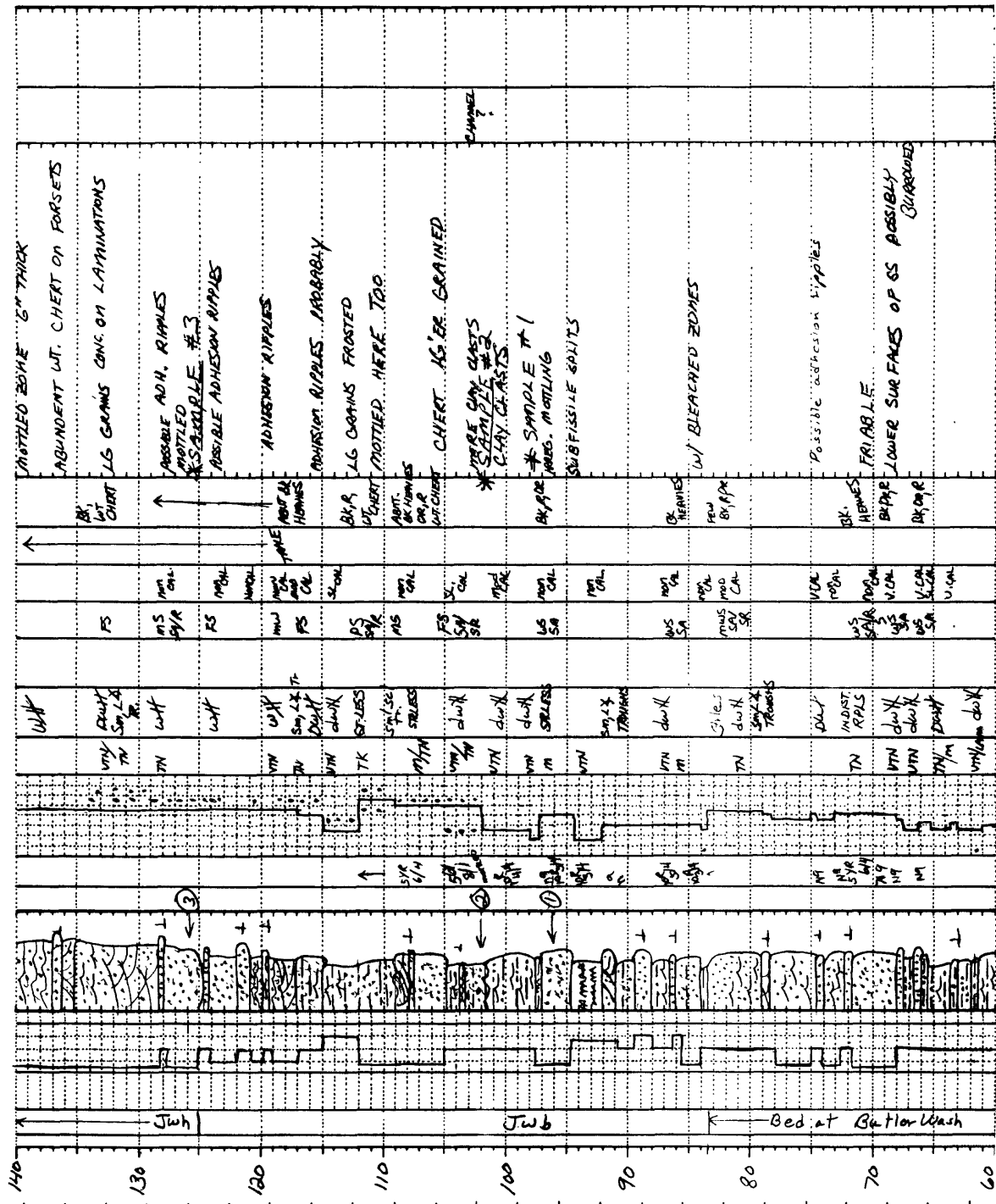


Figure 8. Location of measured section no. 6.

LOCATION ⁶ Tsistah Wash ^{SE 1/4, NW 1/4} Sec. 2 T. 40 N. R. 29 E. (estimated)
 STATE Arizona COUNTY Apache
 U.S.G.S. CORE LIBRARY NUMBER 8/83 API WELL NUMBER CANDEN, HARRIS



LOCATION Ts. TAH. WASH. Sec. 7 T. 40.N. R. 29.E. (C.T.)
 STATE Arizona COUNTY Apache
 U.S.G.S. CORE LIBRARY NUMBER _____ API WELL NUMBER _____



API WELL NUMBER.

35

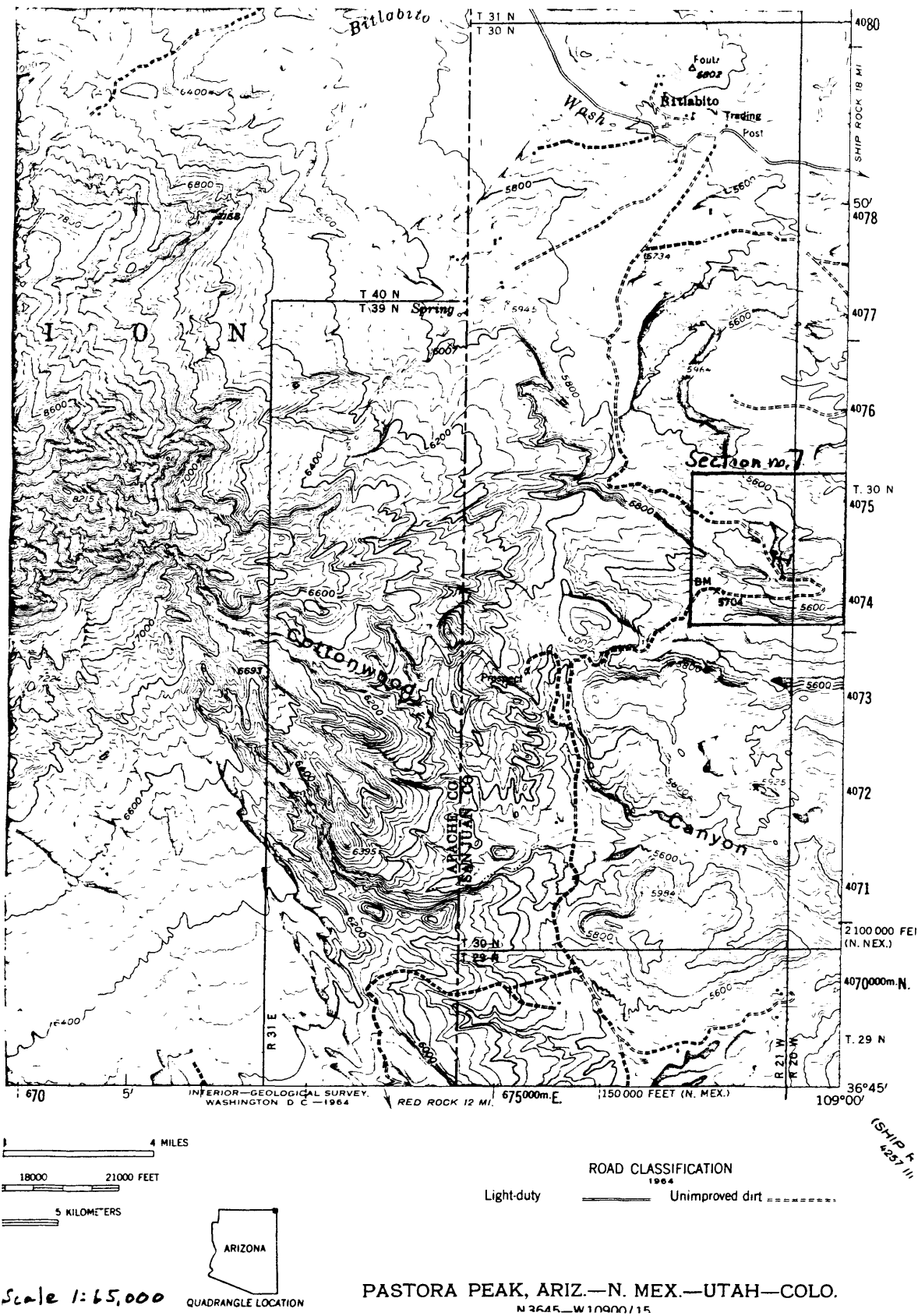
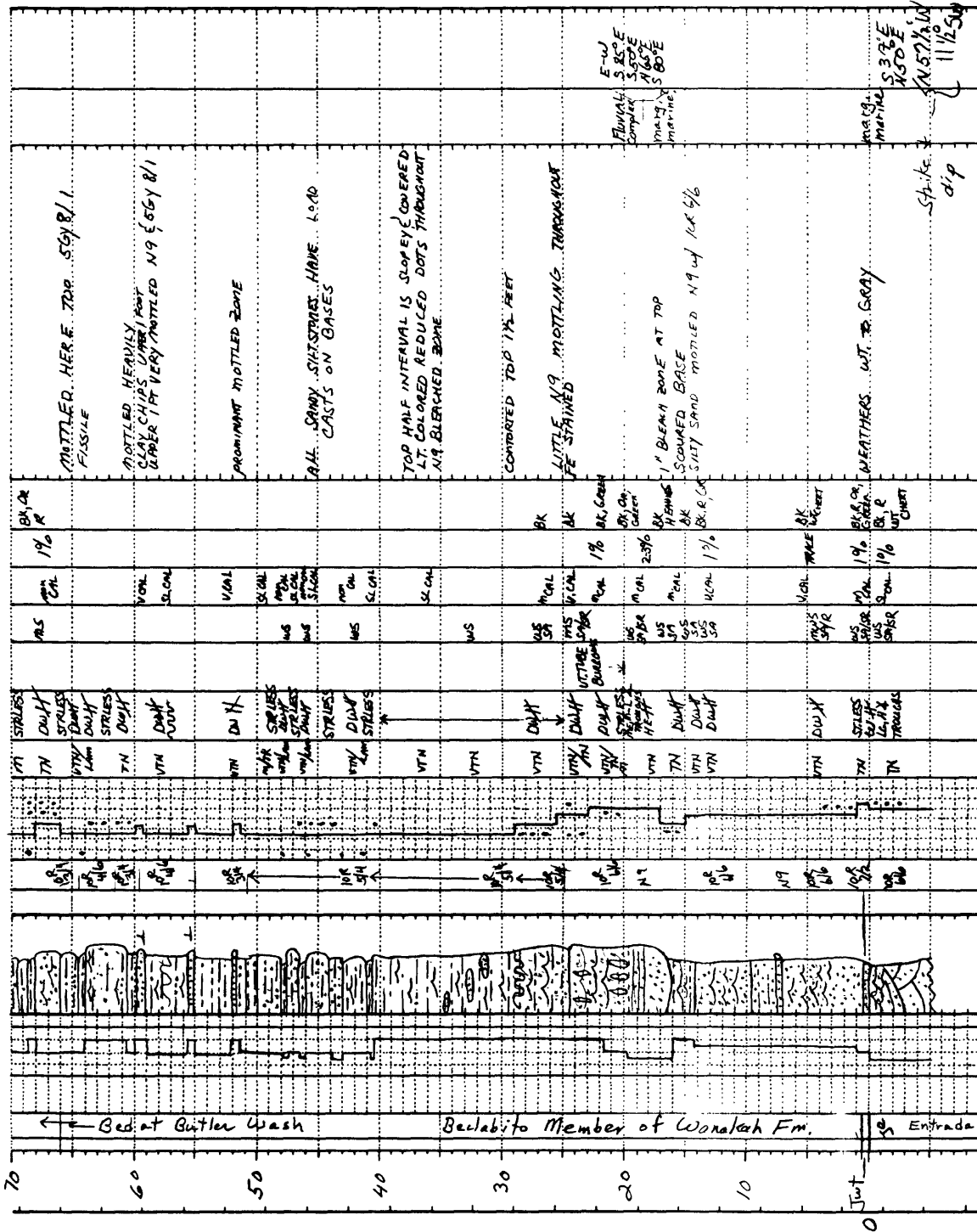
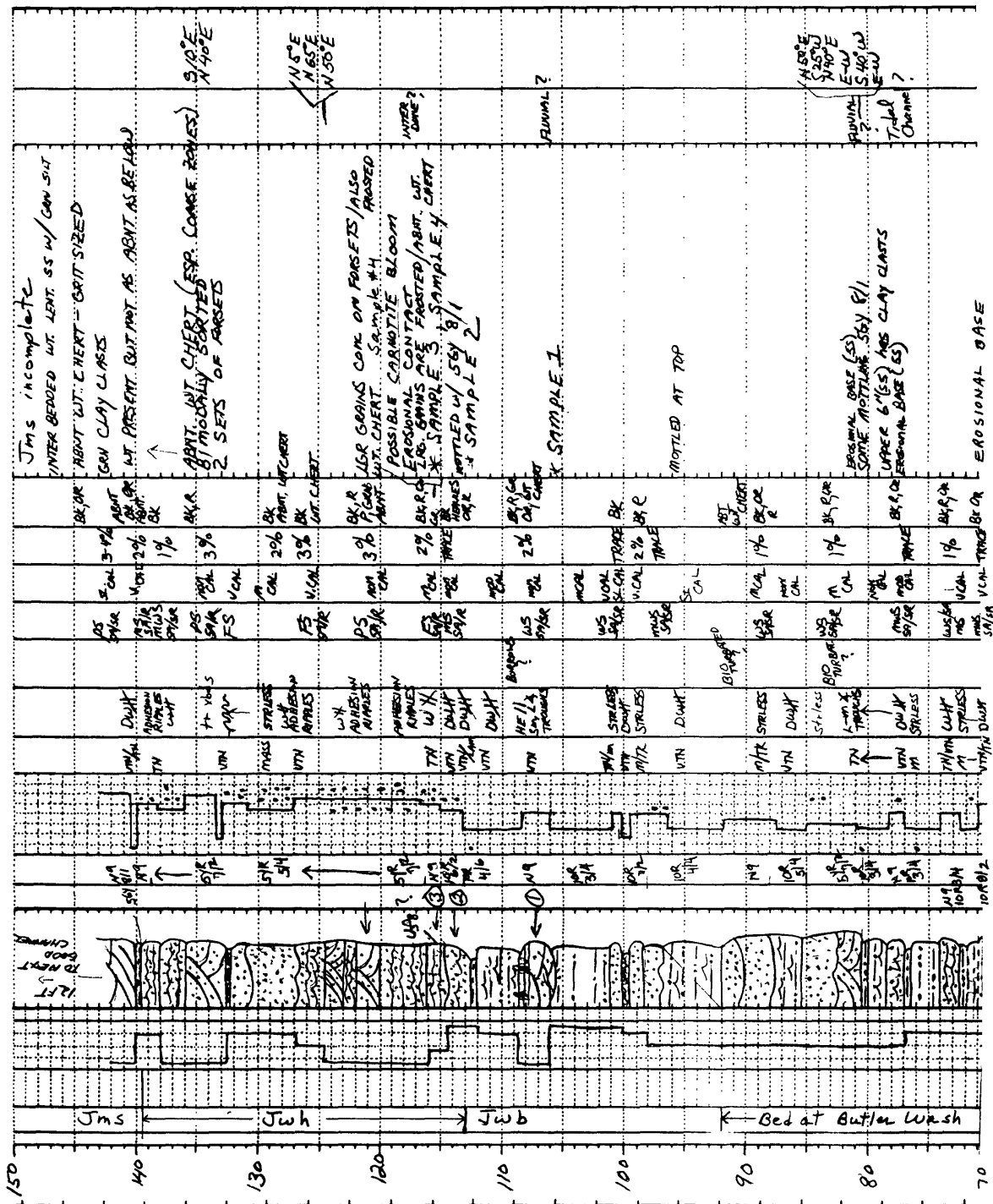


Figure 9. Location of measured section no. 7.

U.S.G.S. CORE LIBRARY NUMBER.....8183.....API WELL NUMBER. CONRON, HARRIS



② LOCATION BE LABITO DOME Sec. 24 T. 30N R. 21W
 STATE New Mexico COUNTY San Juan
 U.S.G.S. CORE LIBRARY NUMBER _____ API WELL NUMBER _____



REDROCK VALLEY QUADRANGLE
ARIZONA—NEW MEXICO
15 MINUTE SERIES (TOPOGRAPHIC)

(RATTLE)

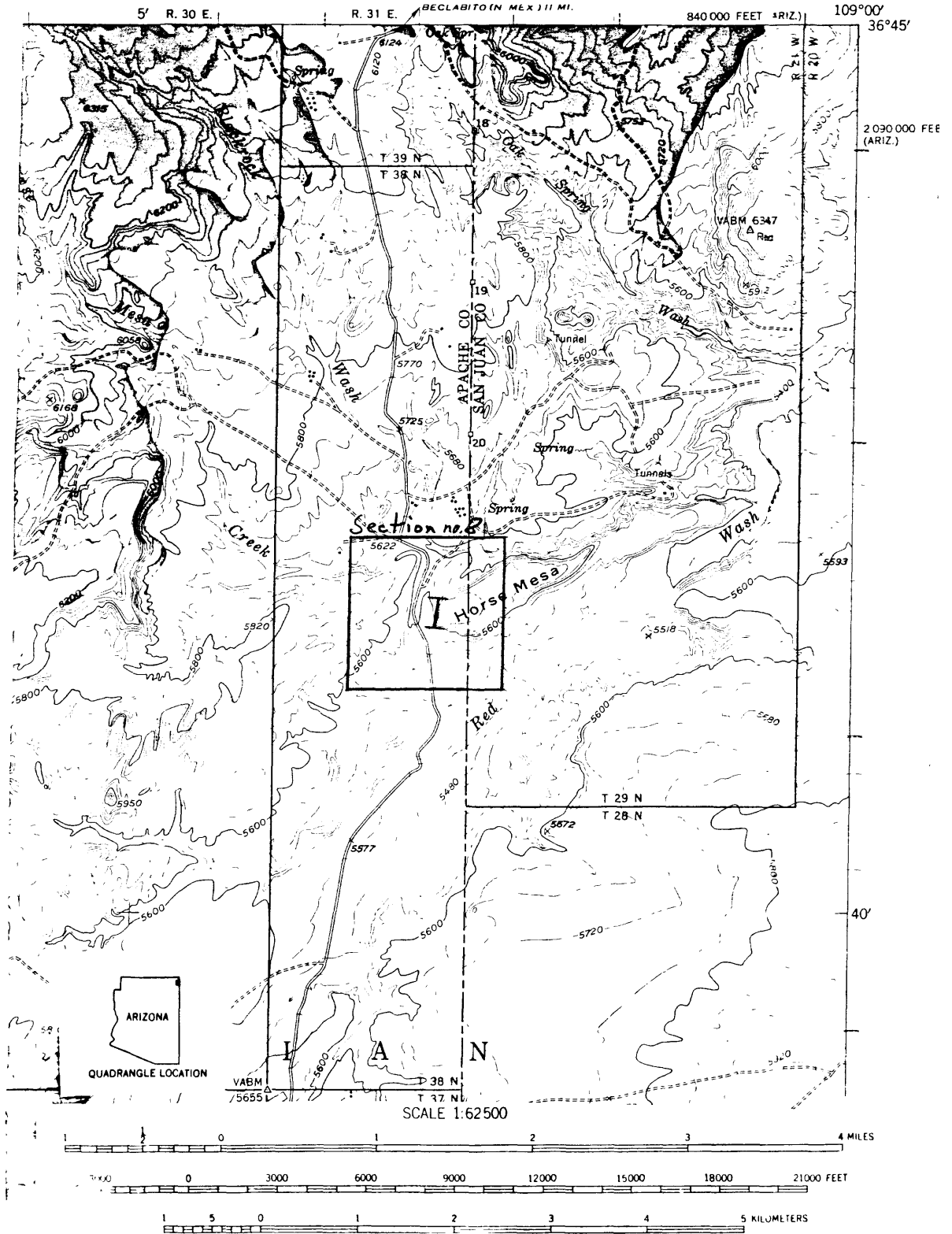


Figure 10. Location of measured section no. 8.

Reference section for Jw in NE Ariz + N.W. N.Mex.

marginal marine
Sakka

massive
Sakka

Limestone
bleached contact

Strike - N31E
Dip - 4° SE

WS
SA

mass shales

mass shales
VTN dark
TK shales
VTN dark
VTN will. Algal
buildings heads
VTN dark
VTN light

100'6"

100'6"

100'6"
SM 7/8
100'4"
100'2"
100'0"

Beclabito Member of Jw

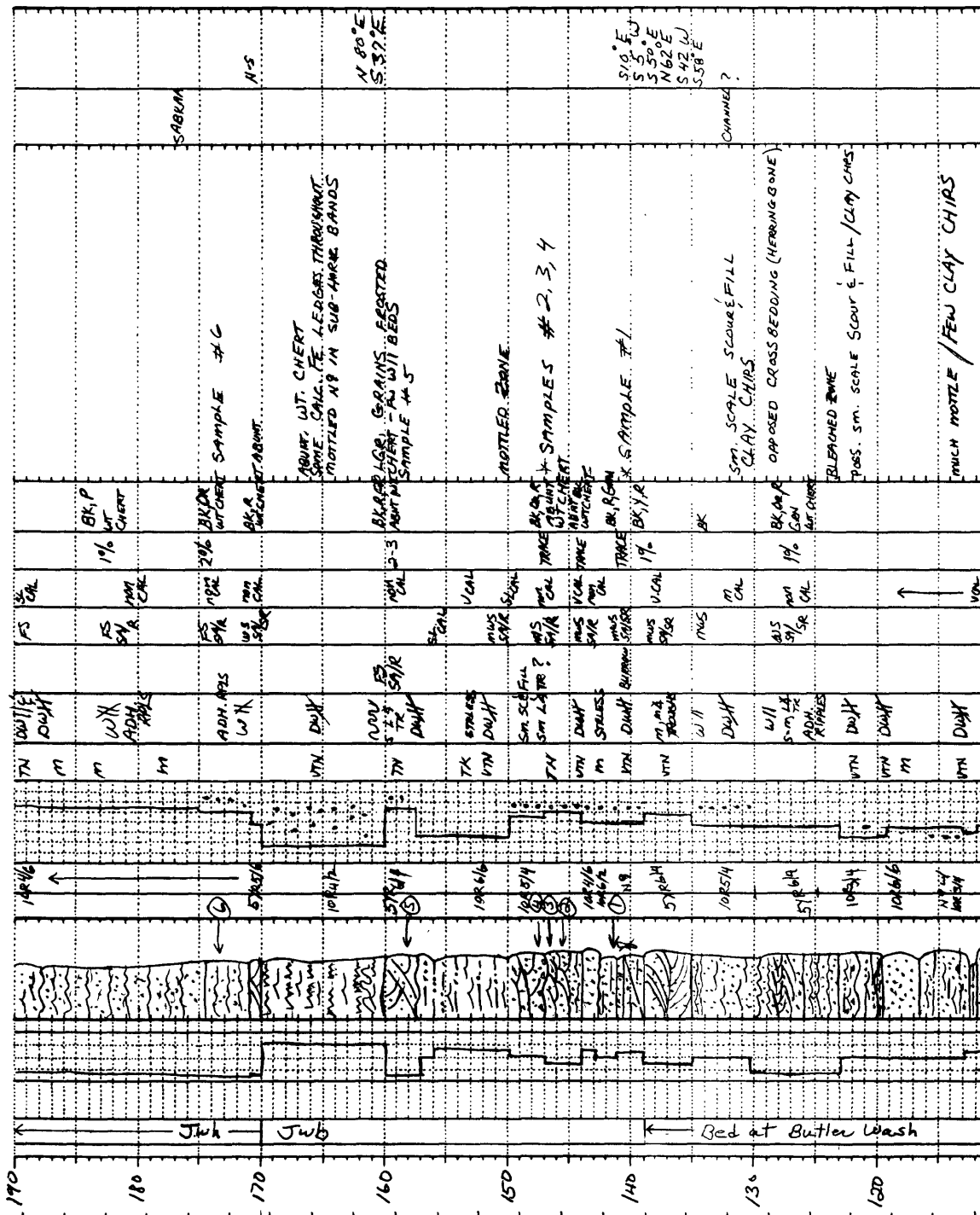
Entrada Sandstone

Jwb
Jwt
0

Bed at Gutter Wash

Beclabito Member of Wanakah Fm

③ LOCATION Horse Mesa Sec. 17 T. 38 N R. 31 E
 STATE Arizona COUNTY Apache
 U.S.G.S. CORE LIBRARY NUMBER _____ API WELL NUMBER _____



LOCATION HOSE MESA Sec. 17 T. 38N R. 31E
STATE Arizona COUNTY Apache
U.S.G.S. CORE LIBRARY NUMBER _____ API WELL NUMBER _____

DEPTH AND FORMATION TOPS	SHOWS FRACTURES (type, angle)	C.P.S.	EXC. POSSIBILITY	CONF.	ROCK TYPE	FOOTNOTES	COLOR	CLAY DOMINANT	GRAIN SIZE	BEDDING (as observed)	SEDIMENTARY STRUCTURES	BIOLOGIC CONSTITUENTS, HUMATE	SORTING / ROUNDNESS	CEMENT	PERCENT PULVER.	ACCESSORY MINERALS OR FRAGMENTS	DESCRIPTION	INFERRED ENVIRONMENT OF DEPOSITION	TRANSPOSED DIRECTION
100																			
200																			
300																			
400																			
500																			
600																			
700																			
800																			
900																			
1000																			
1100																			
1200																			
1300																			
1400																			
1500																			
1600																			
1700																			
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3000																			
3100																			
3200																			
3300																			
3400																			
3500																			
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3800																			
3900																			
4000																			
4100																			
4200																			
4300																			

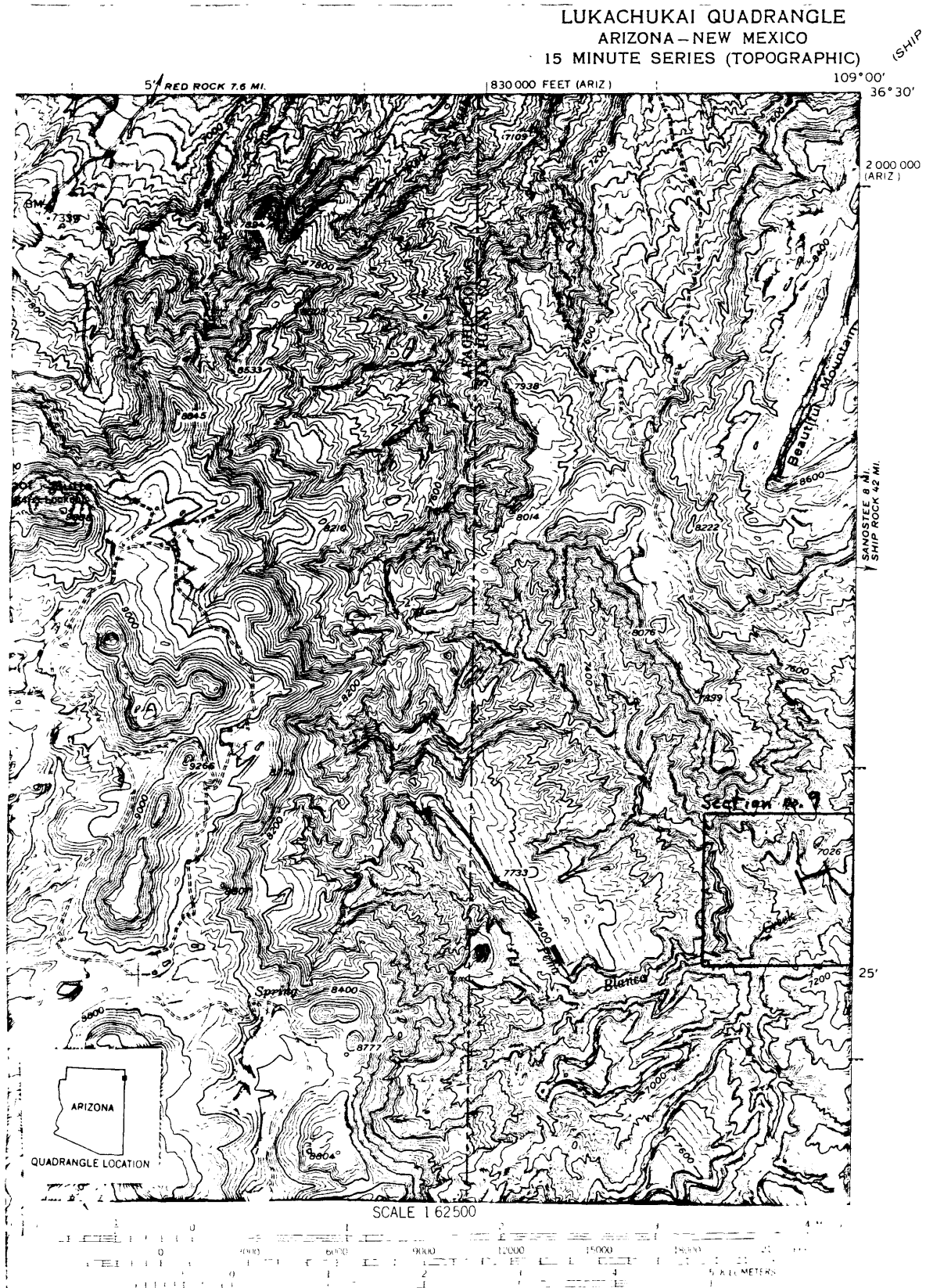
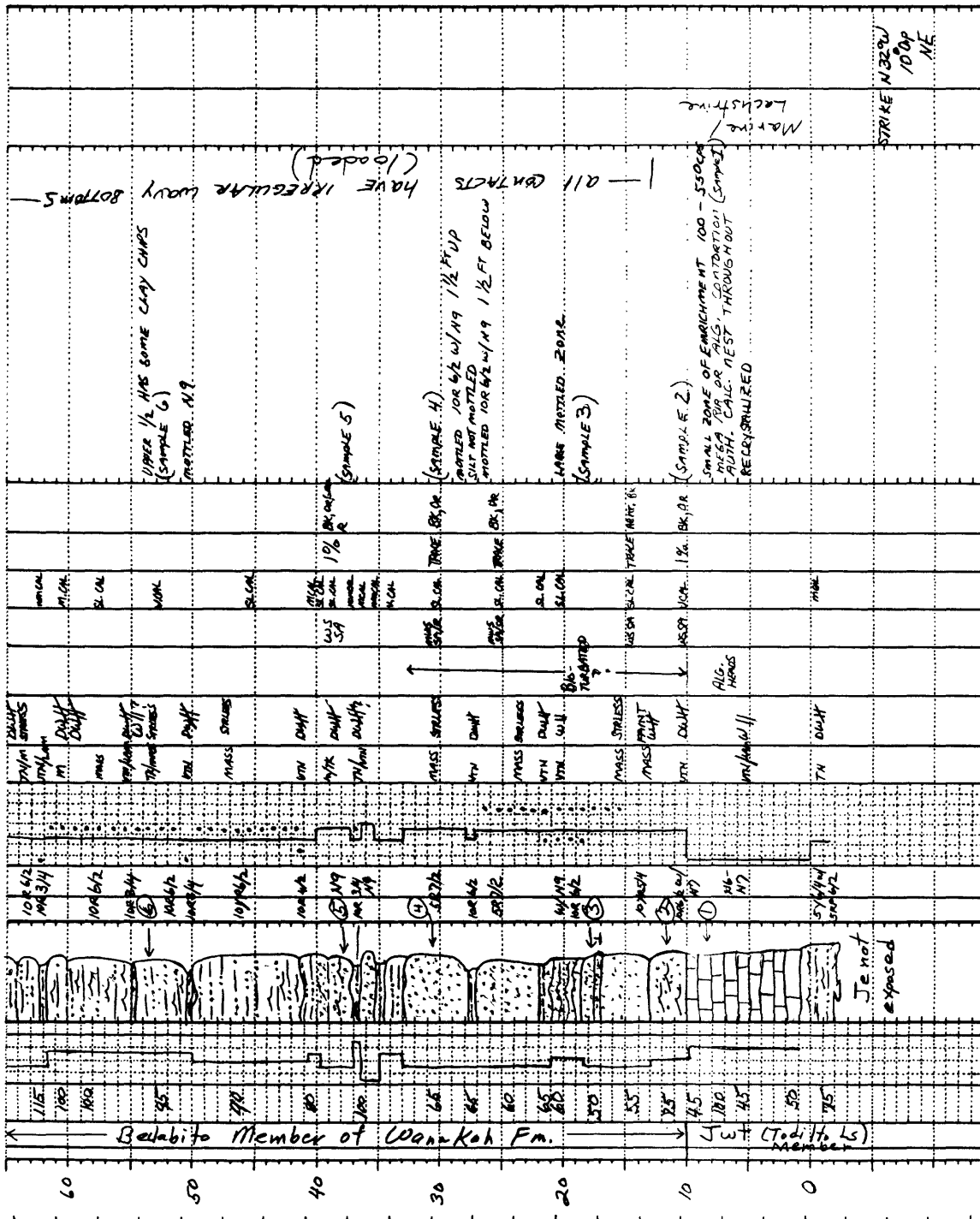


Figure 11. Location of measured section no. 9.

LOCATION ⁹ SANDSTEE WASH Sec. 5 NE 1/4, SE 1/4 T. 25 N. R. 20 W (estimated)
 STATE New Mexico COUNTY San Juan
 U.S.G.S. CORE LIBRARY NUMBER 8183 API WELL NUMBER CANDAN, HARRIS



API WELL NUMBER



③

→ Tims Channel

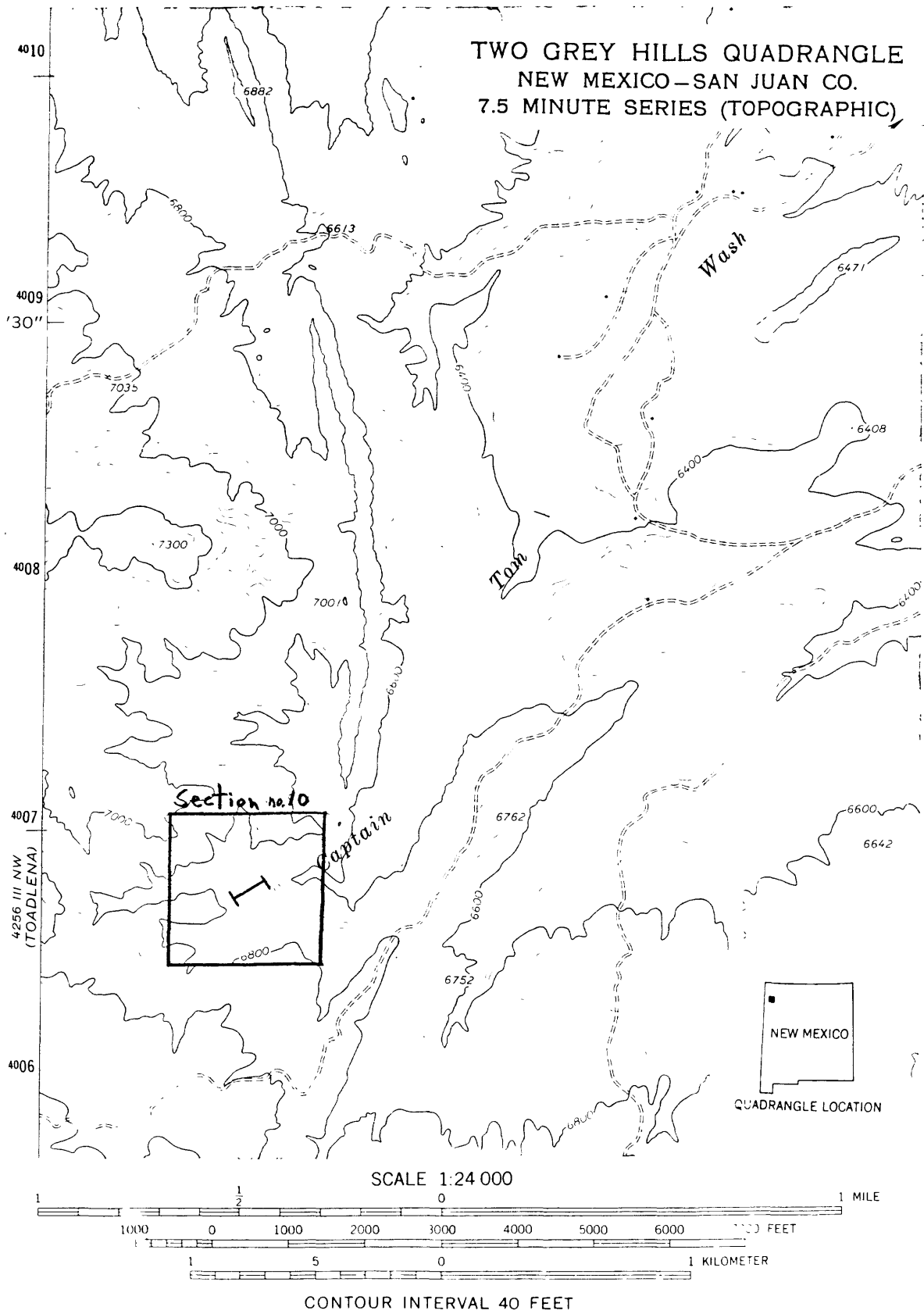
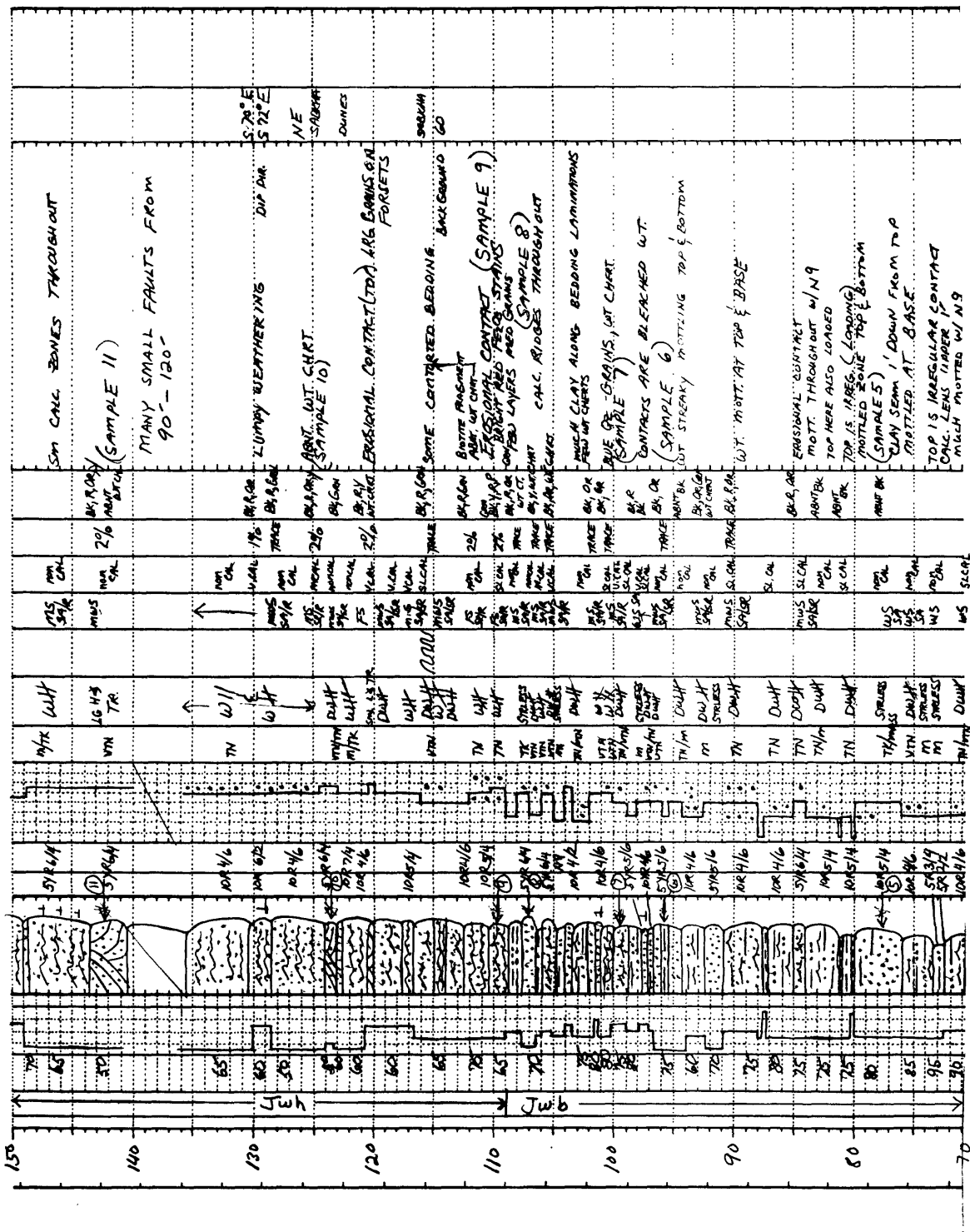


Figure 12. Location of measured section no. 10.

Geological log of the Beclabito Member of the Wanakah Formation. The log shows a stratigraphic column with various rock units and their thicknesses. Key features include a 'Shallow shelf / Isobathic' zone at the top, a 'Grad. contact' zone, and a 'Wavy bedding near top' zone. The log is divided into sections labeled 'Sample 1' and 'Sample 2'. The bottom section is labeled 'Beclabito Member of Wanakah Formation'.

Unit	Thickness (ft)	Notes
Shallow shelf / Isobathic	~10	Offset across wash. 85 yards
Grad. contact	~10	Grad. contact
Wavy bedding near top	~10	Organics on some bedding planes
Sample 1	~10	As reconstituted - full range of grain size
Sample 2	~10	Auth calcite nests
Silt zone	~10	
Beclabito Member of Wanakah Formation	~10	

LOCATION TADOLENA Sec. 33 T. 23N R. 19E (estimated)
 STATE New Mexico COUNTY San Juan
 U.S.G.S. CORE LIBRARY NUMBER _____ API WELL NUMBER _____



LOCATION TOADLENA Sec. 33 T. 23N. R. 19W (estimated)
 STATE New Mexico COUNTY San Juan
 U.S.G.S. CORE LIBRARY NUMBER _____ API WELL NUMBER _____

DEPTH AND FORMATION TOPS	SHOWS FRACTURES (if any)	C.P.S.	Est. VISUAL POSSIBILITY	Core Notes	ROCK TYPE	FOOTNOTES	COLOR	Cls DOMINANT	Cls GRAIN	Bedding Size	Bedding (as observed)	SEDIMENTARY STRUCTURES	BIOLOGIC CONSTITUENTS	Sorting Mudstone	Cement	PERCENT Feldspar	ACCESSORY MINERALS OR FRAGMENTS	DESCRIPTION	INFERRED ENVIRONMENT OF DEPOSITION	TRANSVERSE DIRECTION
150																				
160																				
170																				
175																				
180																				
185																				
190																				
195																				
200																				
205																				
210																				
215																				
220																				
225																				
230																				
235																				
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245																				
250																				
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410																				
415																				
420																				
425																				
430																				
435																				
440																				
445																				
450																				
455																				
460																				
465																				
470																				
475																				
480																				
485																				
490																				
495																				
500																				

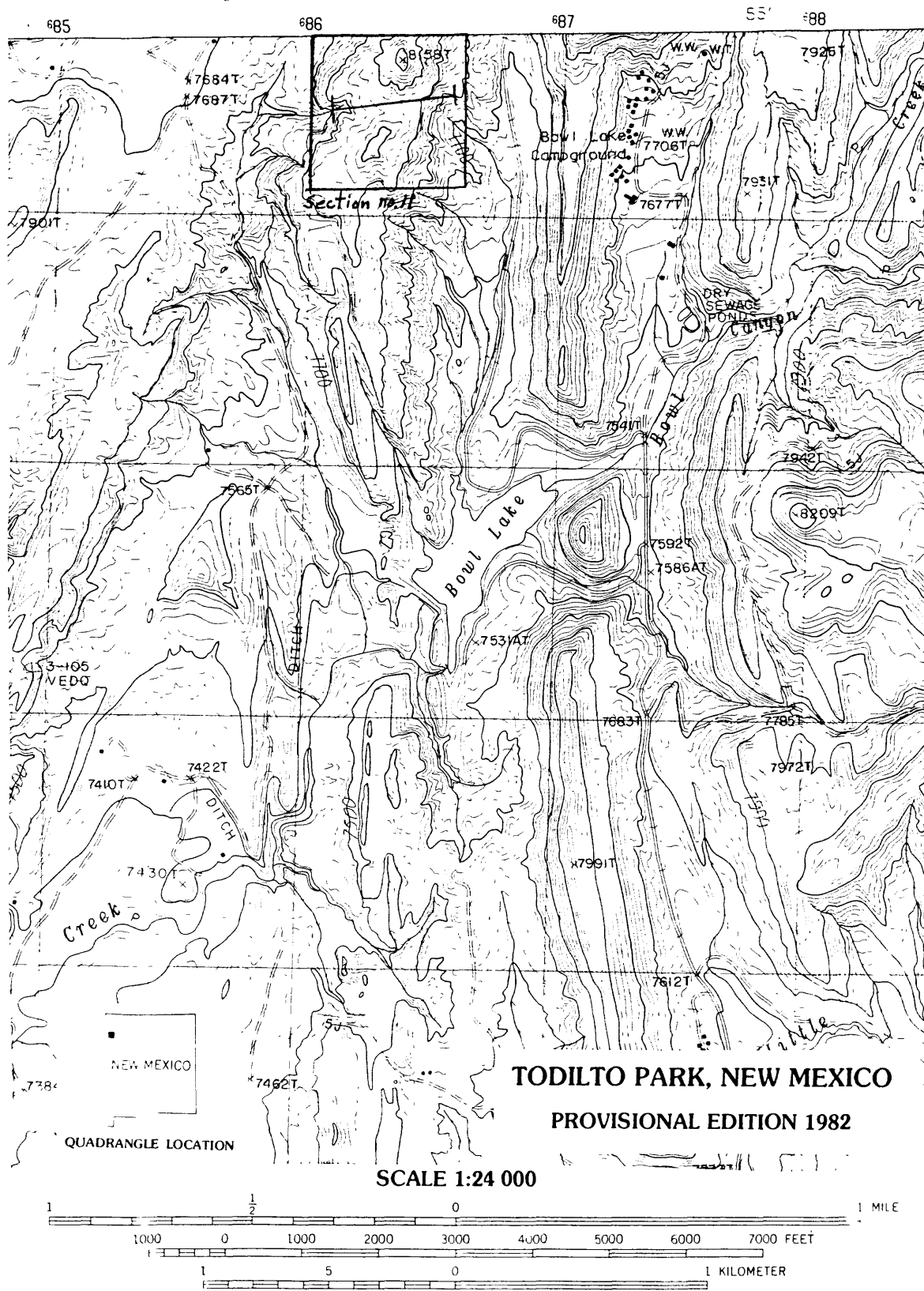
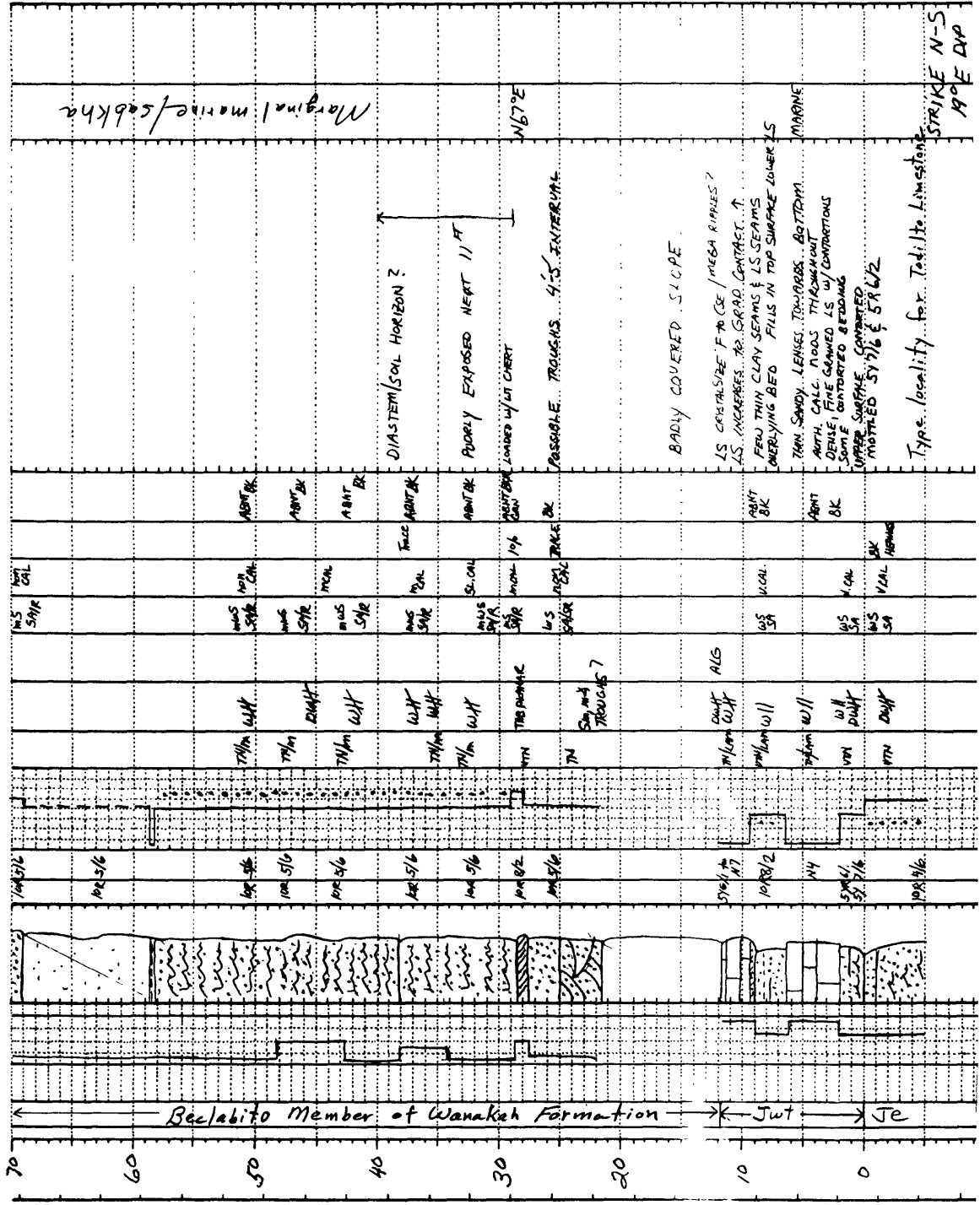
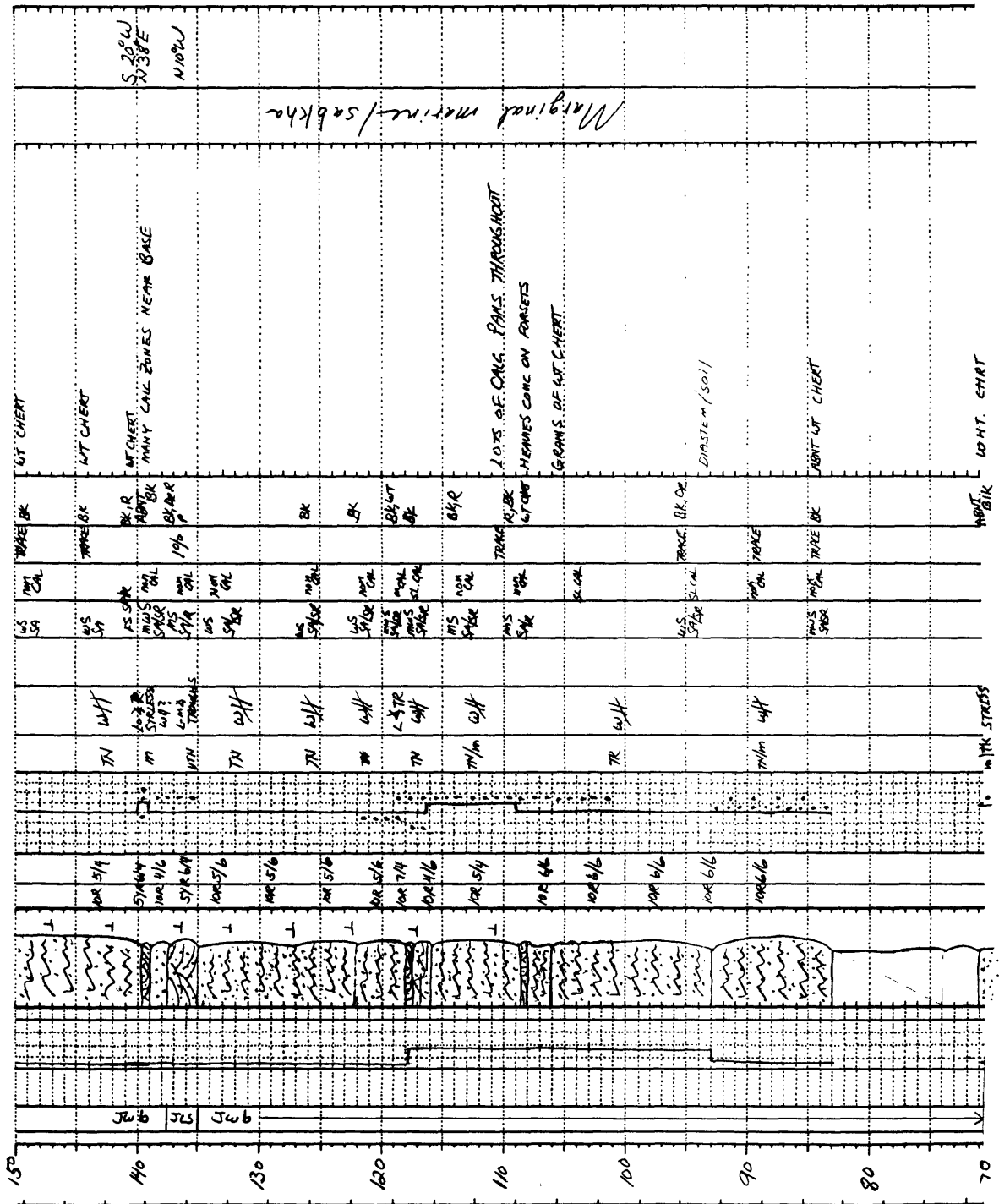


Figure 13. Location of measured section no. 11.

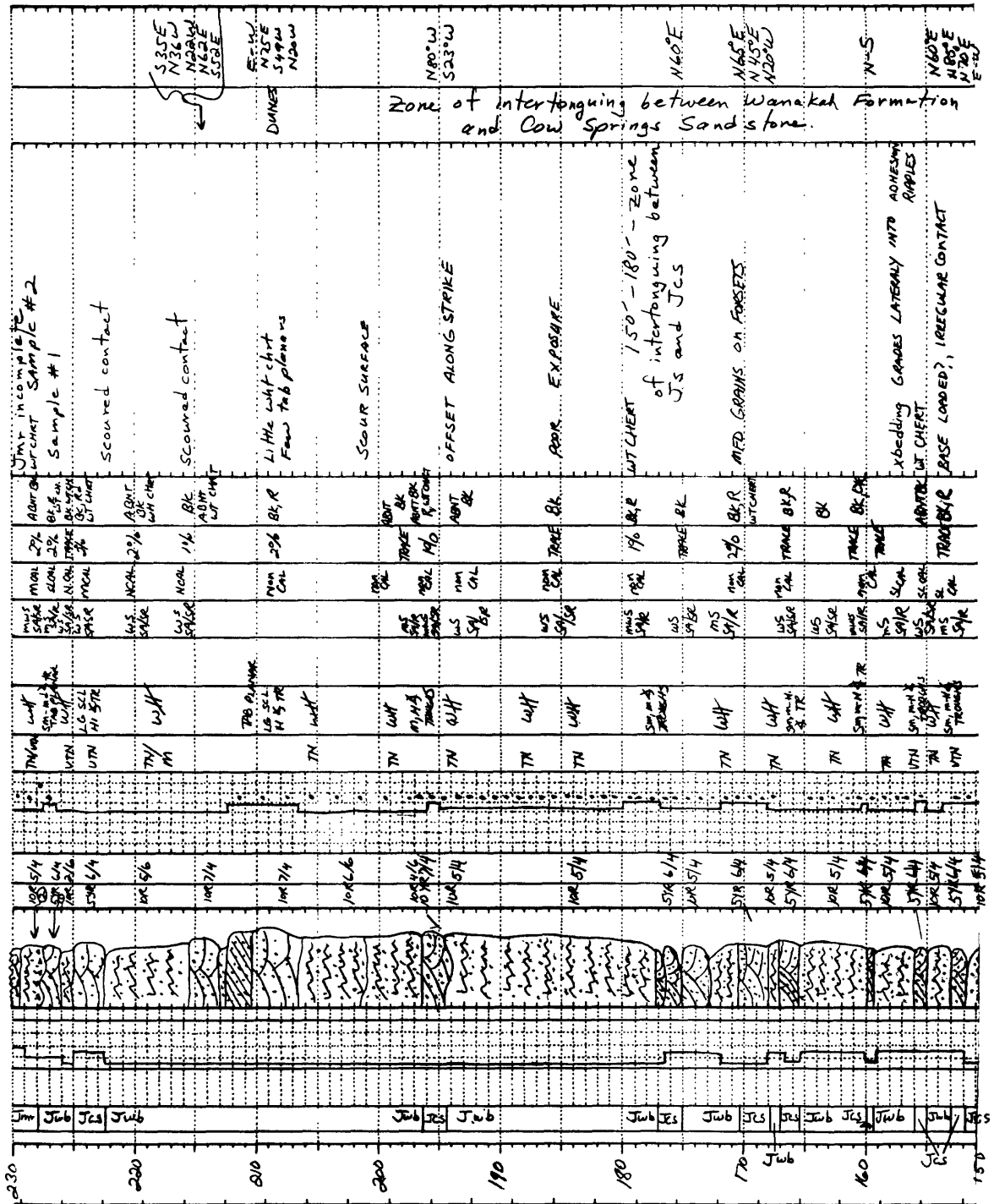
LOCATION ¹¹ Todillo Park Sec. 13 T. 20 N. R. 20 W. (estimated)
 STATE New Mexico COUNTY Mckinley
 U.S.G.S. CORE LIBRARY NUMBER 8/83 API WELL NUMBER CANDAN, HARRIS



U.S.G.S. CORE LIBRARY NUMBER.....API WELL NUMBER.....



LOCATION Todillo Park Sec. 13 T. 20N R. 20W (estimated)
 STATE New Mexico COUNTY McKinley
 U.S.G.S. CORE LIBRARY NUMBER _____ API WELL NUMBER _____



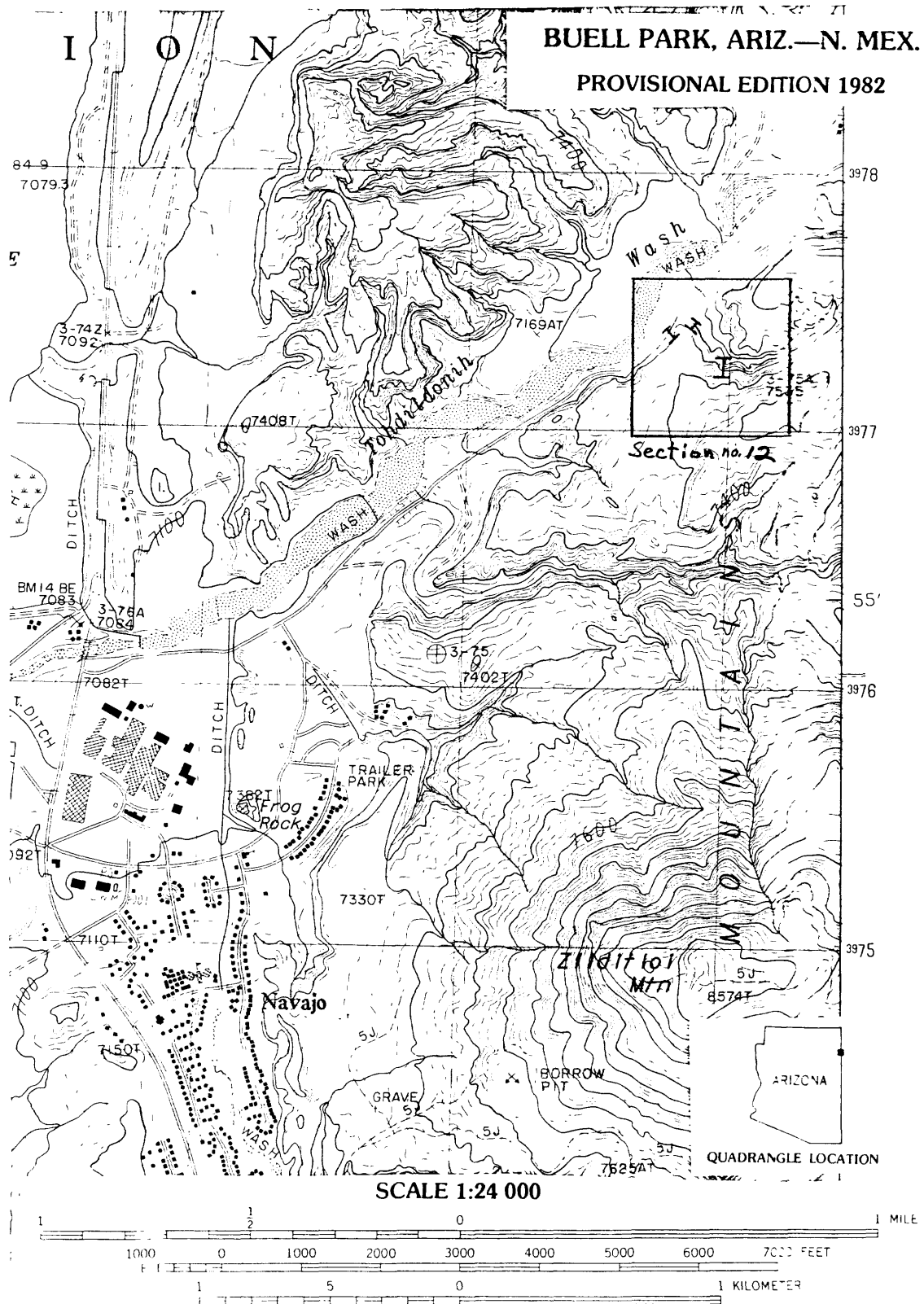
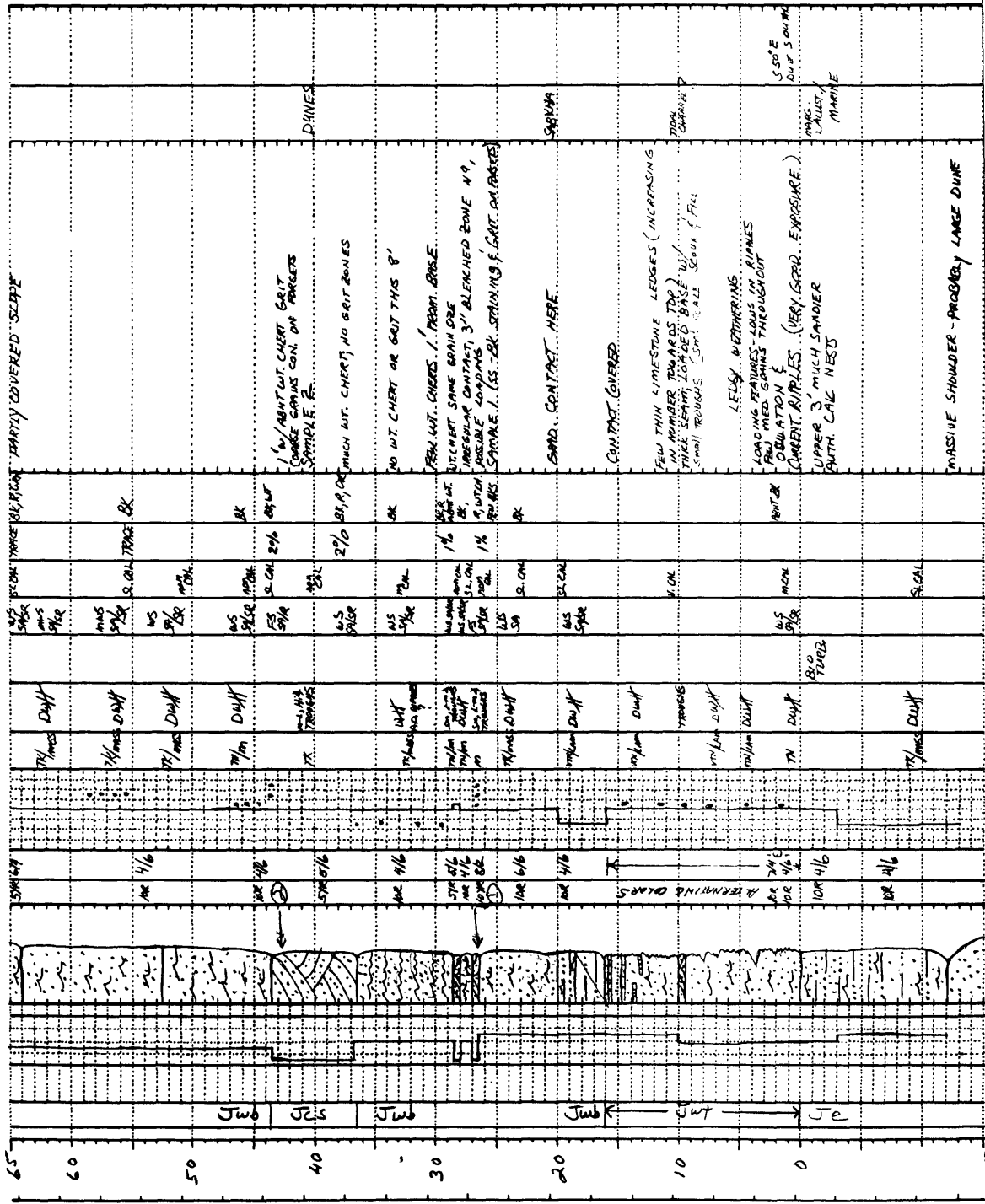


Figure 14. Location of measured section no. 12.

LOCATION ¹² Navajo E 1/2, NE 1/4 Sec. 31 T. 20 N. R. 20 W. (estimated)
 STATE New Mexico COUNTY McKinley
 U.S.G.S. CORE LIBRARY NUMBER 8183 API WELL NUMBER CONDON, HARRIS



②



	TR/Less LG, H ₂ O TRENCHES	US SPICE	M/CAL	BK,R	DUNES
225	TH/Less LG, H ₂ O TRENCHES	US SPICE	M/CAL	BK,R	DUNES
220	TH/Less LG, H ₂ O TRENCHES	US SPICE	M/CAL	BK,R	DUNES
210	TH/Less LG, H ₂ O TRENCHES	US SPICE	M/CAL	BK,R	DUNES
200	TH/Less LG, H ₂ O TRENCHES	US SPICE	M/CAL	BK,R	DUNES
190	TH/Less LG, H ₂ O TRENCHES	US SPICE	M/CAL	BK,R	DUNES
180	TH/Less LG, H ₂ O TRENCHES	US SPICE	M/CAL	BK,R	DUNES
170	TH/Less LG, H ₂ O TRENCHES	US SPICE	M/CAL	BK,R	DUNES
160	TH/Less LG, H ₂ O TRENCHES	US SPICE	M/CAL	BK,R	DUNES
150	TH/Less LG, H ₂ O TRENCHES	US SPICE	M/CAL	BK,R	DUNES
145	TH/Less LG, H ₂ O TRENCHES	US SPICE	M/CAL	BK,R	DUNES

LOCATION Navajo Sec. 31 T. 20 N R. 20 W (estimated)
 STATE New Mexico COUNTY Mckinley
 U.S.G.S. CORE LIBRARY NUMBER _____ API WELL NUMBER _____

DEPTH/MT	FORMATION	SHOES	FRACTURES (rep. only)	C.P. 2	VISUAL	POSS. ESTIMATE	CONT.	ROCK TYPE	FOOTNOTES	COLOR	CLAY DOMINANT	GRAIN	SIZE	BEDDING	STRUCTURES	BIOLOGIC	CONSTITUENTS	HUMATE	SOFTING	BOUNDNESS	CEMENT	PERCENT	ACCESSORY	MINERALS OR	FRAGMENTS	DESCRIPTION	INFERRED ENVIRONMENT	DIRECTION OF DEPOSITION	THICKNESS
245																													
240																													
235																													
230																													
225																													

SIMILAR TO TWIN BUTTES SECT.
CLIFF ABOVE FLUVIAL HAS LG
DUNES
UNIT 5'S MORE CSE (GRANULAR)
SAMPLE 8
SAMPLE 7
COARSE GRAINS--ANGULAR, RUTTER
BKN CLY CLASTS / MUCH CHERT
ONE DIEGROWTHS
CONCRETES PLACING
SMALL WT CHERTS
FAINT BEDDING / POSSIBLE BURROWS
SAMPLE 5
FEW WT. CHERTS
Sample 5
Some wt chert

**FORT DEFIANCE QUADRANGLE
ARIZONA—NEW MEXICO
7.5 MINUTE SERIES (TOPOGRAPHIC)**

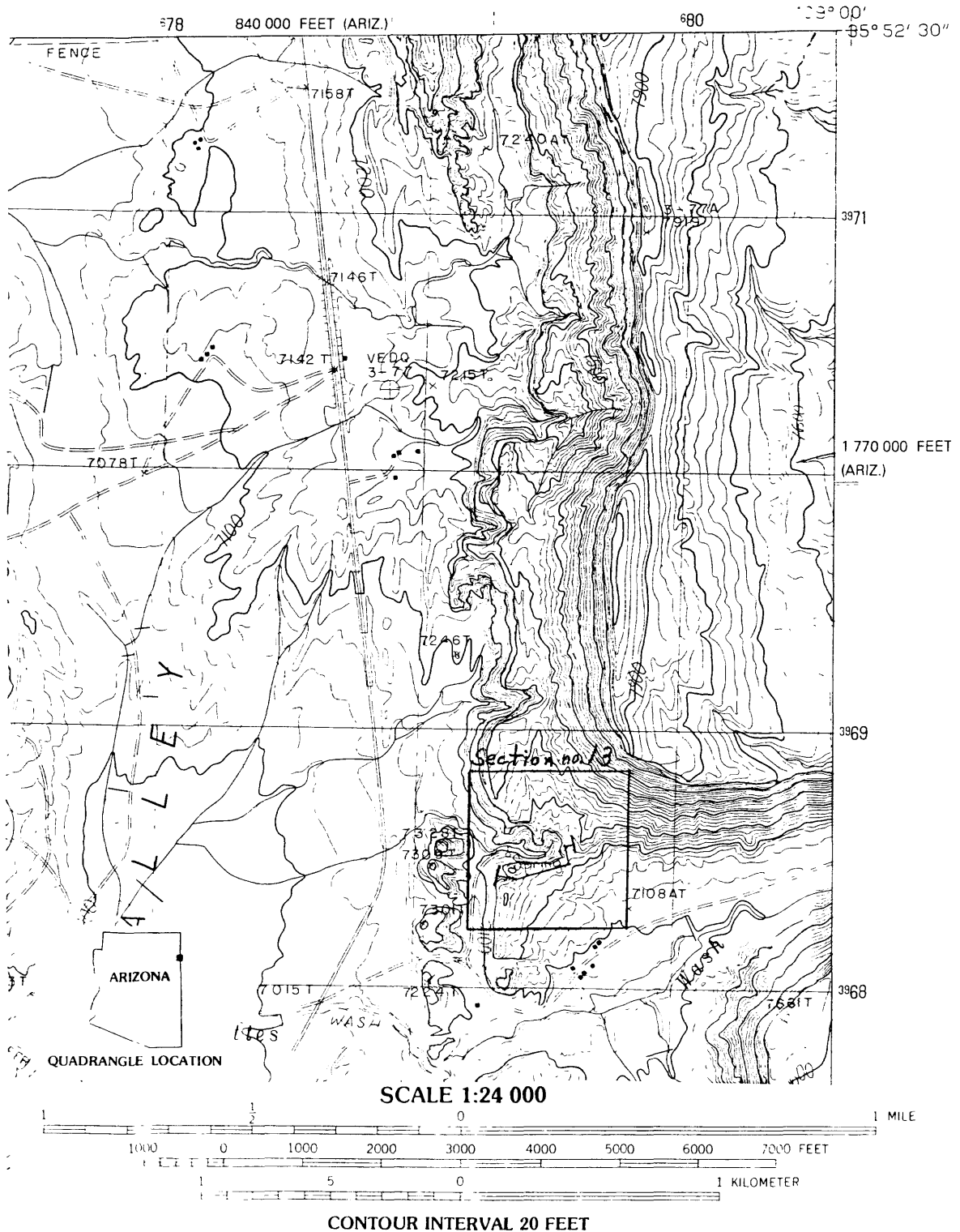
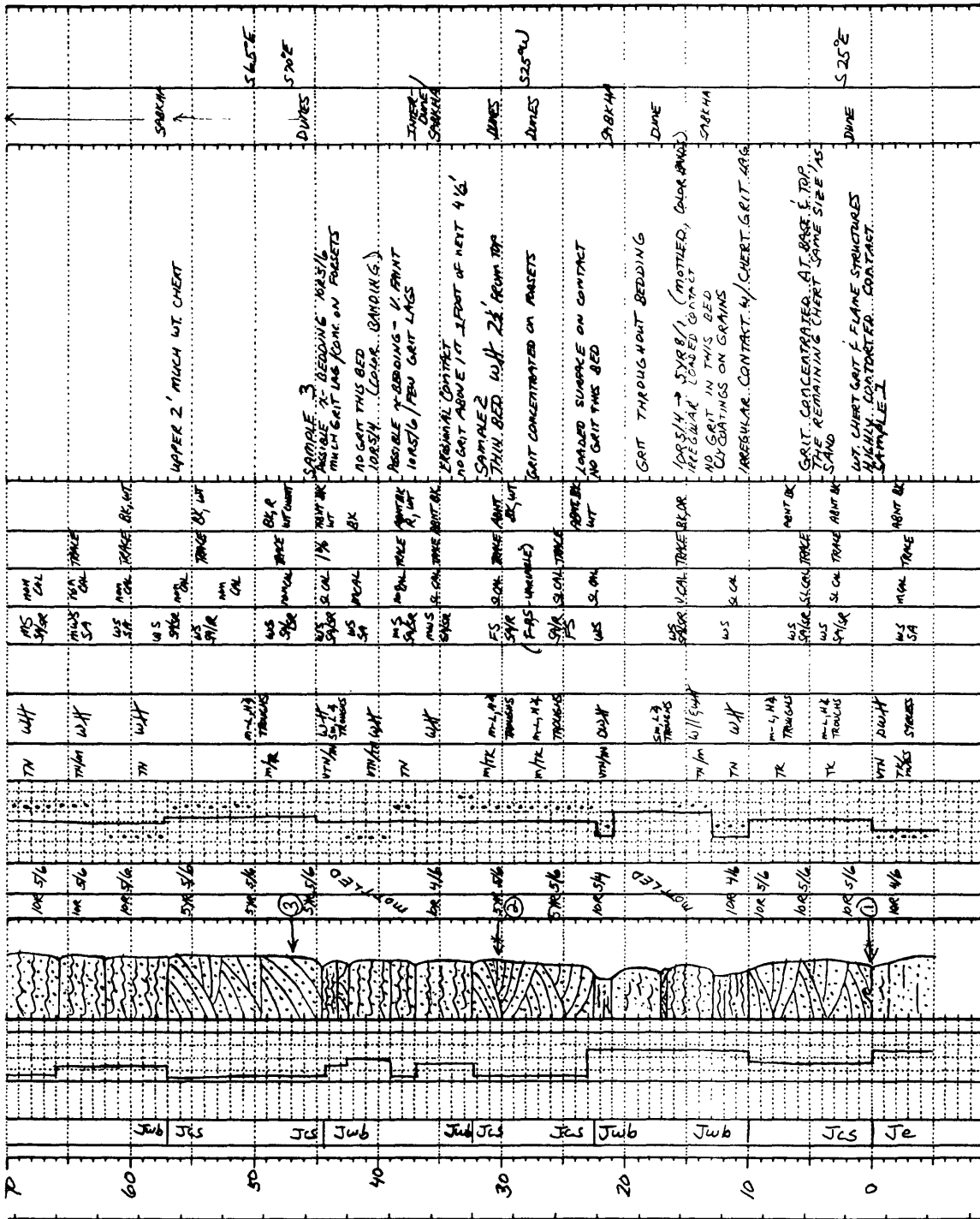


Figure 15. Location of measured section no. 13.

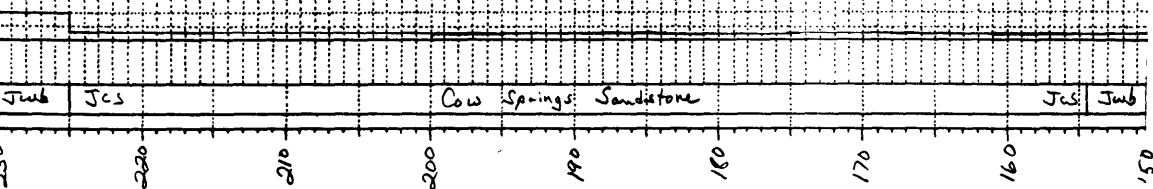
LOCATION ^{13-T} TWIN BUTTES ^{E 1/2, NW 1/4} Sec. 30 T. 19 N. R. 20 W. (estimated)
STATE New Mexico COUNTY McKinley
U.S.G.S. CORE LIBRARY NUMBER 8/83 API WELL NUMBER CONDON, HARRIS



API WELL NUMBER



API WELL NUMBER



LOCATION TWIN BITES Sec. 30 T. 19N R. 20W (estimated)
 STATE New Mexico COUNTY McKinley
 U.S.G.S. CORE LIBRARY NUMBER _____ API WELL NUMBER _____

DEPTH AND FORMATION TOPS	SHOWS	FRACTURES (Type, angle)	C.P.S.	EXC. VISUAL POROSITY	CORE	ROCK TYPE	FOOTNOTES	COLOR	CLAY DOMINANT	GRAIN	SIZE	BEDDING (as observed)	SEDIMENTARY STRUCTURES	BIOLOGIC CONSTITUENTS	SORTING	BOUNDARIES	CEMENT	PERCENT	ACCESSORY MINERALS OR PHASES	DESCRIPTION	INFERRED ENVIRONMENT OF DEPOSITION	TRANSPORT DIRECTION
230																						
220																						
210																						
200																						
190																						
180																						
170																						
160																						
150																						
140																						
130																						
120																						
110																						
100																						
90																						
80																						
70																						
60																						
50																						
40																						
30																						
20																						
10																						
0																						

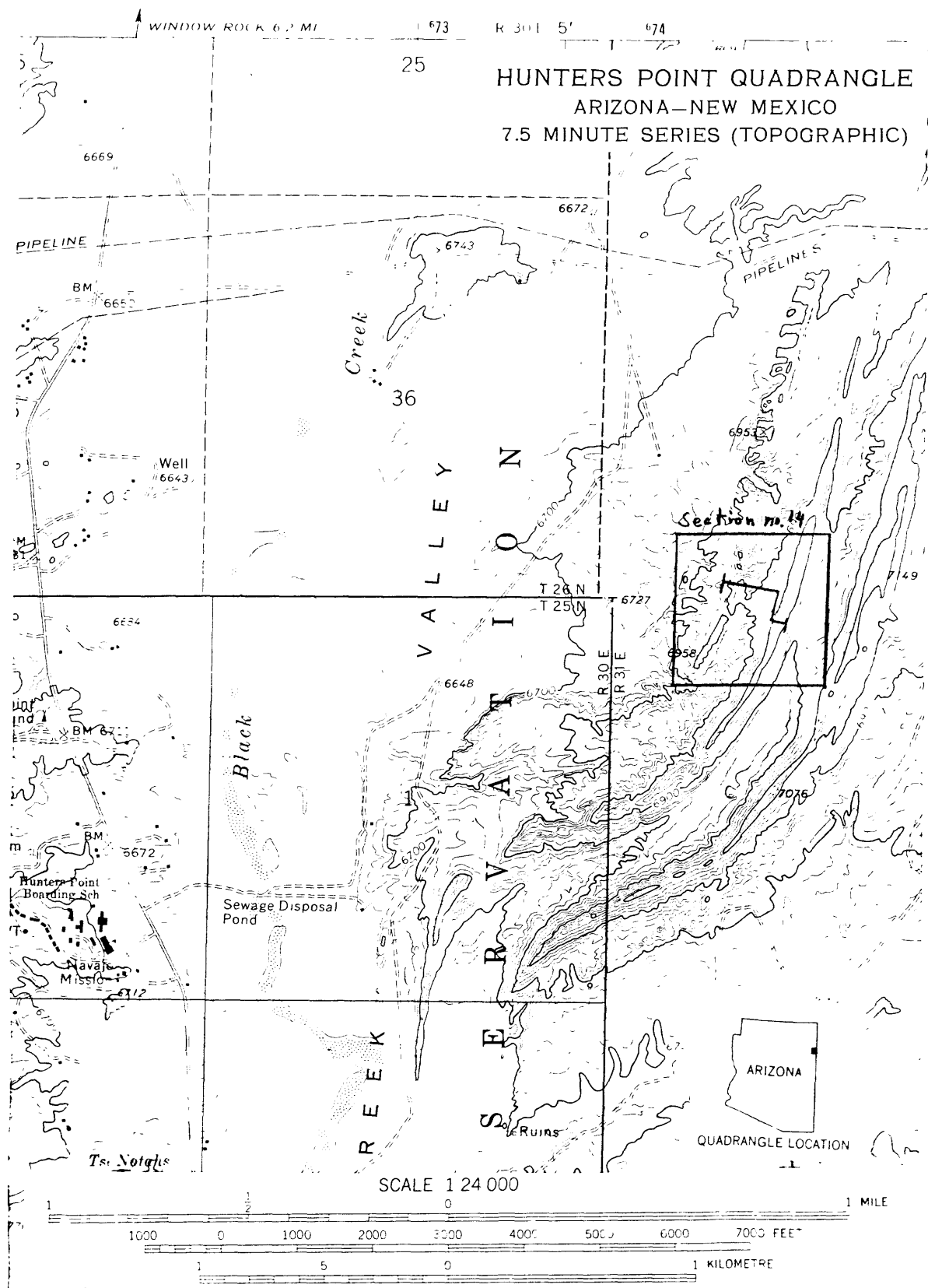


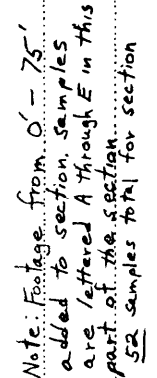
Figure 16. Location of measured section no. 14.

LOCATION ¹⁴Pipeline Road Sec. ^{SE 1/4, SW 1/4} 30 T. 26 N. R. 31 E (estimated)

COUNTY... Apache

U.S.G.S. CORE LIBRARY NUMBER.....6180

API WELL NUMBER CONDOY, McDonnell

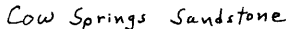


LOCATION Pueblo Road Sec. 30 T. 26 N R. 31 E (est.)
 STATE Arizona COUNTY Apache
 LATITUDE AND LONGITUDE

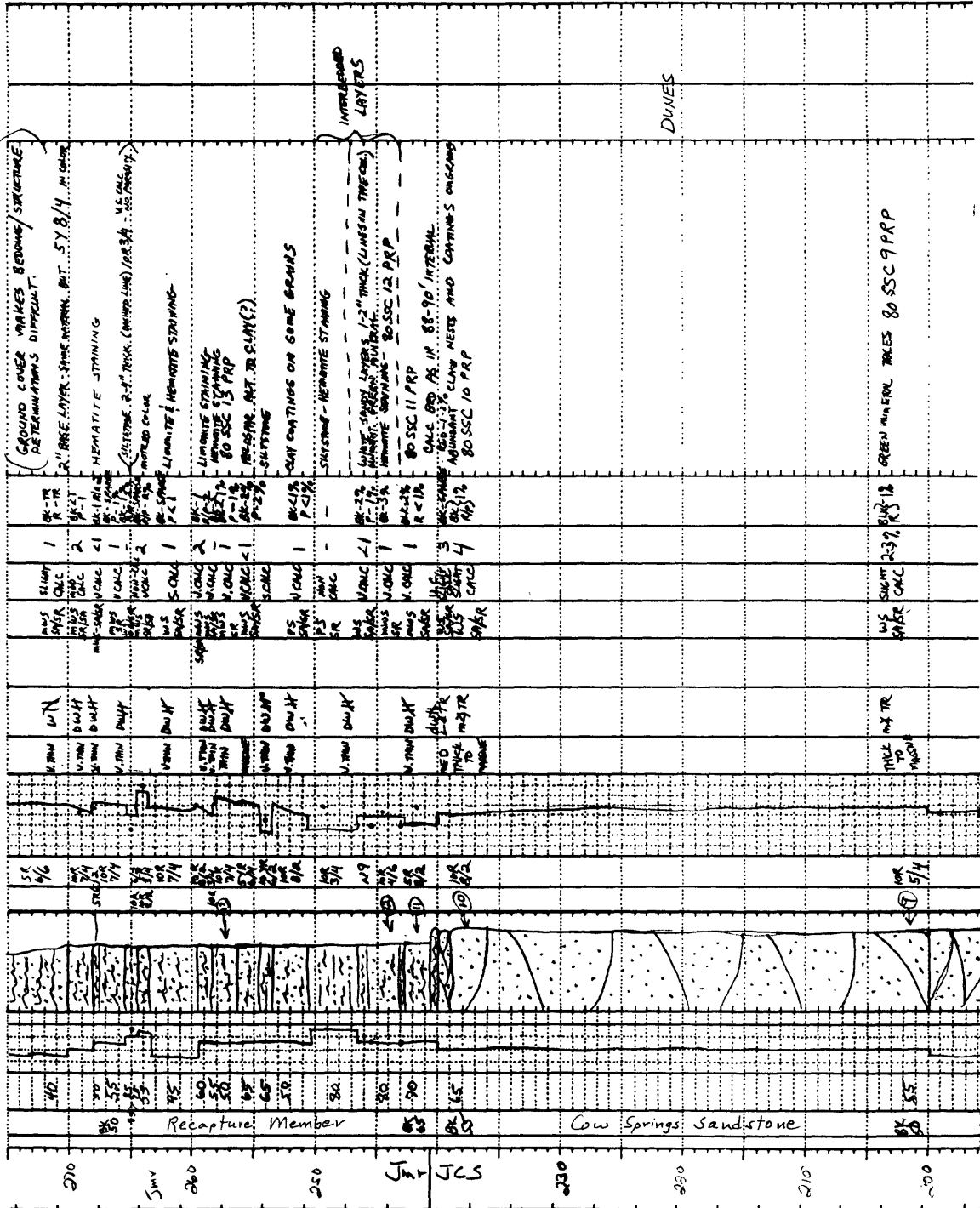
DEPTH AND FORMATION TYPE	SHOVS	FRACTURES (FIPS./INCH)	C.P. 2	Visual Porosity	Core	ROCK TYPE	FOOTNOTES	COLOR	CLAY DOMINANT	GRAIN SIZE	BEDDING (as observed)	SEDIMENTARY STRUCTURES	BIOLOGIC CONSTITUENTS	SCORING	CEMENT	PERCENT	ACCESSORY MINERALS OR FRAGMENTS	DESCRIPTION	INFERRED ENVIRONMENT OF DEPOSITION	TRANSPORT DIRECTION
110																			DUNE	ALSO W
105	65	60					⑤	10/8			THIN TR. 1/2"	10-12 TR. 1/2"		10-12 TR. 1/2"	2-3	2%	OK-TR. 1/2"	CLAY CONC. & COATINGS SHARP STAINING BEDDING ADHESIVE STAINING - MINERITE STAIN 1/4" 2" BED 1' FROM BOTTOM	INTER- DUNE	
100	65	60					⑥	10/8			THIN 1/4"	10-12 TR. 1/2"		10-12 TR. 1/2"	2-3	2%	OK-TR. 1/2"	CLAY CONC. & COATINGS SHARP STAINING BEDDING ADHESIVE STAINING - MINERITE STAIN 1/4" 2" BED 1' FROM BOTTOM	INTER- DUNE	
95	65	60					⑦	10/8			THIN 1/4"	10-12 TR. 1/2"		10-12 TR. 1/2"	2-3	2%	OK-TR. 1/2"	CLAY CONC. & COATINGS SHARP STAINING BEDDING ADHESIVE STAINING - MINERITE STAIN 1/4" 2" BED 1' FROM BOTTOM	INTER- DUNE	
90	65	60					⑧	10/8			THIN 1/4"	10-12 TR. 1/2"		10-12 TR. 1/2"	2-3	2%	OK-TR. 1/2"	CLAY CONC. & COATINGS SHARP STAINING BEDDING ADHESIVE STAINING - MINERITE STAIN 1/4" 2" BED 1' FROM BOTTOM	INTER- DUNE	
85	65	60					⑨	10/8			THIN 1/4"	10-12 TR. 1/2"		10-12 TR. 1/2"	2-3	2%	OK-TR. 1/2"	CLAY CONC. & COATINGS SHARP STAINING BEDDING ADHESIVE STAINING - MINERITE STAIN 1/4" 2" BED 1' FROM BOTTOM	INTER- DUNE	
80	65	60					⑩	10/8			THIN 1/4"	10-12 TR. 1/2"		10-12 TR. 1/2"	2-3	2%	OK-TR. 1/2"	CLAY CONC. & COATINGS SHARP STAINING BEDDING ADHESIVE STAINING - MINERITE STAIN 1/4" 2" BED 1' FROM BOTTOM	INTER- DUNE	
75	65	60					⑪	10/8			THIN 1/4"	10-12 TR. 1/2"		10-12 TR. 1/2"	2-3	2%	OK-TR. 1/2"	CLAY CONC. & COATINGS SHARP STAINING BEDDING ADHESIVE STAINING - MINERITE STAIN 1/4" 2" BED 1' FROM BOTTOM	INTER- DUNE	
70	65	60					⑫	10/8			THIN 1/4"	10-12 TR. 1/2"		10-12 TR. 1/2"	2-3	2%	OK-TR. 1/2"	CLAY CONC. & COATINGS SHARP STAINING BEDDING ADHESIVE STAINING - MINERITE STAIN 1/4" 2" BED 1' FROM BOTTOM	INTER- DUNE	
65	65	60					⑬	10/8			THIN 1/4"	10-12 TR. 1/2"		10-12 TR. 1/2"	2-3	2%	OK-TR. 1/2"	CLAY CONC. & COATINGS SHARP STAINING BEDDING ADHESIVE STAINING - MINERITE STAIN 1/4" 2" BED 1' FROM BOTTOM	INTER- DUNE	
60	65	60					⑭	10/8			THIN 1/4"	10-12 TR. 1/2"		10-12 TR. 1/2"	2-3	2%	OK-TR. 1/2"	CLAY CONC. & COATINGS SHARP STAINING BEDDING ADHESIVE STAINING - MINERITE STAIN 1/4" 2" BED 1' FROM BOTTOM	INTER- DUNE	
55	65	60					⑮	10/8			THIN 1/4"	10-12 TR. 1/2"		10-12 TR. 1/2"	2-3	2%	OK-TR. 1/2"	CLAY CONC. & COATINGS SHARP STAINING BEDDING ADHESIVE STAINING - MINERITE STAIN 1/4" 2" BED 1' FROM BOTTOM	INTER- DUNE	
50	65	60					⑯	10/8			THIN 1/4"	10-12 TR. 1/2"		10-12 TR. 1/2"	2-3	2%	OK-TR. 1/2"	CLAY CONC. & COATINGS SHARP STAINING BEDDING ADHESIVE STAINING - MINERITE STAIN 1/4" 2" BED 1' FROM BOTTOM	INTER- DUNE	
45	65	60					⑰	10/8			THIN 1/4"	10-12 TR. 1/2"		10-12 TR. 1/2"	2-3	2%	OK-TR. 1/2"	CLAY CONC. & COATINGS SHARP STAINING BEDDING ADHESIVE STAINING - MINERITE STAIN 1/4" 2" BED 1' FROM BOTTOM	INTER- DUNE	
40	65	60					⑱	10/8			THIN 1/4"	10-12 TR. 1/2"		10-12 TR. 1/2"	2-3	2%	OK-TR. 1/2"	CLAY CONC. & COATINGS SHARP STAINING BEDDING ADHESIVE STAINING - MINERITE STAIN 1/4" 2" BED 1' FROM BOTTOM	INTER- DUNE	
35	65	60					⑲	10/8			THIN 1/4"	10-12 TR. 1/2"		10-12 TR. 1/2"	2-3	2%	OK-TR. 1/2"	CLAY CONC. & COATINGS SHARP STAINING BEDDING ADHESIVE STAINING - MINERITE STAIN 1/4" 2" BED 1' FROM BOTTOM	INTER- DUNE	
30	65	60					⑳	10/8			THIN 1/4"	10-12 TR. 1/2"		10-12 TR. 1/2"	2-3	2%	OK-TR. 1/2"	CLAY CONC. & COATINGS SHARP STAINING BEDDING ADHESIVE STAINING - MINERITE STAIN 1/4" 2" BED 1' FROM BOTTOM	INTER- DUNE	
25	65	60					㉑	10/8			THIN 1/4"	10-12 TR. 1/2"		10-12 TR. 1/2"	2-3	2%	OK-TR. 1/2"	CLAY CONC. & COATINGS SHARP STAINING BEDDING ADHESIVE STAINING - MINERITE STAIN 1/4" 2" BED 1' FROM BOTTOM	INTER- DUNE	
20	65	60					㉒	10/8			THIN 1/4"	10-12 TR. 1/2"		10-12 TR. 1/2"	2-3	2%	OK-TR. 1/2"	CLAY CONC. & COATINGS SHARP STAINING BEDDING ADHESIVE STAINING - MINERITE STAIN 1/4" 2" BED 1' FROM BOTTOM	INTER- DUNE	
15	65	60					㉓	10/8			THIN 1/4"	10-12 TR. 1/2"		10-12 TR. 1/2"	2-3	2%	OK-TR. 1/2"	CLAY CONC. & COATINGS SHARP STAINING BEDDING ADHESIVE STAINING - MINERITE STAIN 1/4" 2" BED 1' FROM BOTTOM	INTER- DUNE	
10	65	60					㉔	10/8			THIN 1/4"	10-12 TR. 1/2"		10-12 TR. 1/2"	2-3	2%	OK-TR. 1/2"	CLAY CONC. & COATINGS SHARP STAINING BEDDING ADHESIVE STAINING - MINERITE STAIN 1/4" 2" BED 1' FROM BOTTOM	INTER- DUNE	
5	65	60					㉕	10/8			THIN 1/4"	10-12 TR. 1/2"		10-12 TR. 1/2"	2-3	2%	OK-TR. 1/2"	CLAY CONC. & COATINGS SHARP STAINING BEDDING ADHESIVE STAINING - MINERITE STAIN 1/4" 2" BED 1' FROM BOTTOM	INTER- DUNE	

Low Springs Sandstone

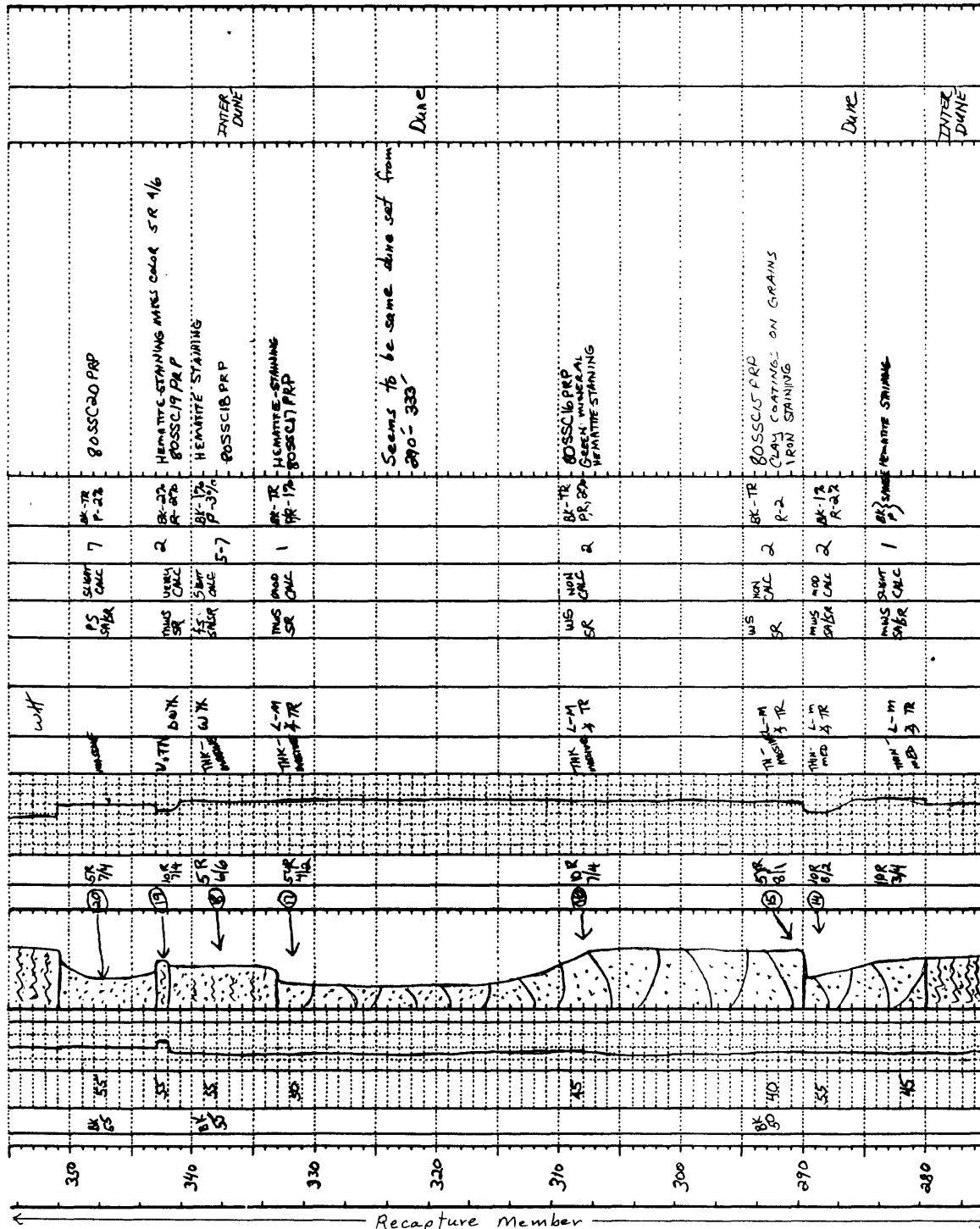
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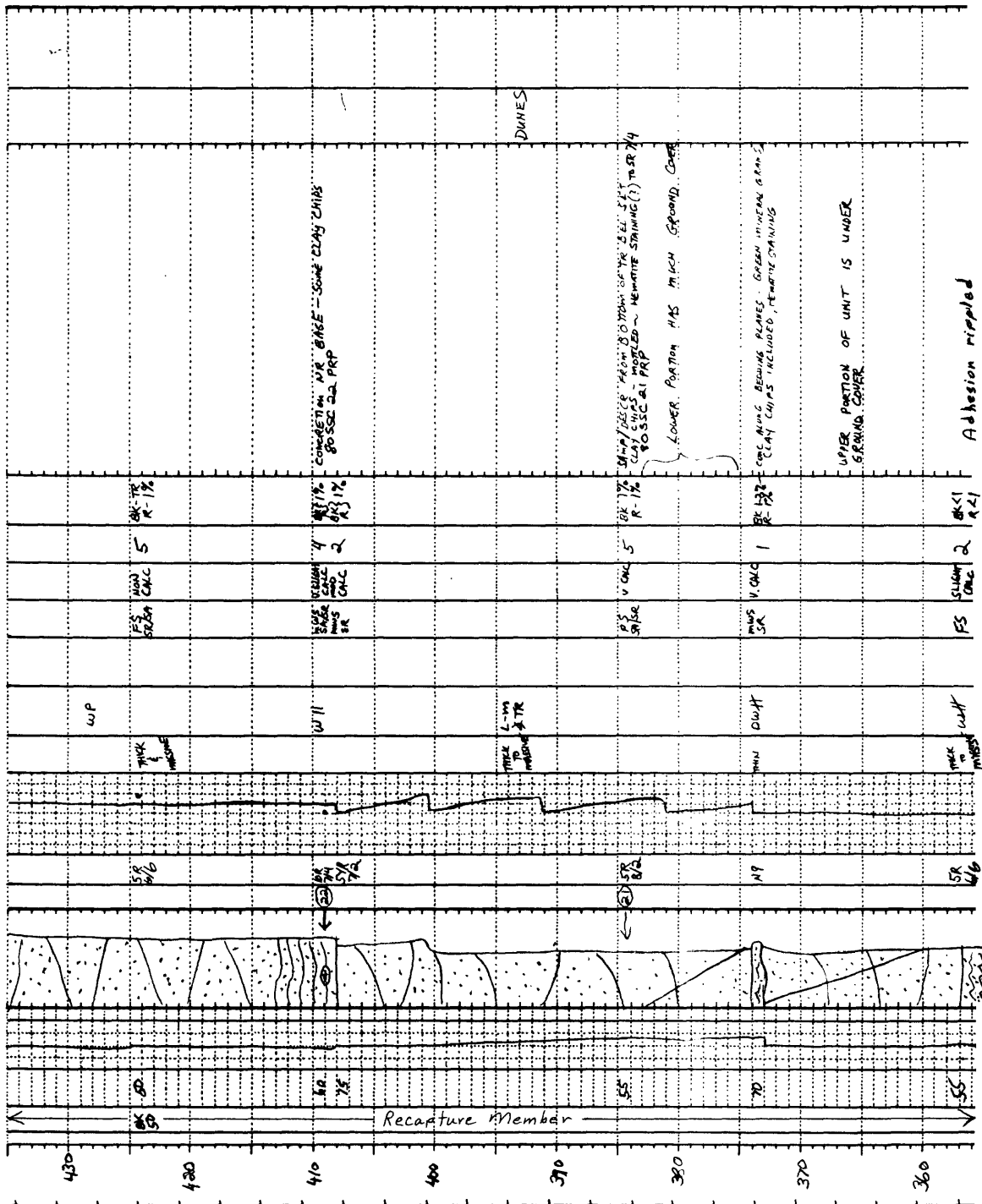
LOCATION Pipe Line Road Sec. 30 T. 24N. R. 31E (est.)
 STATE Arizona COUNTY Apache
 U.S.G.S. CORE LIBRARY NUMBER _____ API WELL NUMBER _____



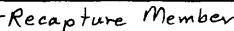
LOCATION Pipeline Road Sec. 30 T. 26N R. 31E (est.)
 STATE Arizona COUNTY Apache
 U.S.G.S. CORE LIBRARY NUMBER _____ API WELL NUMBER _____



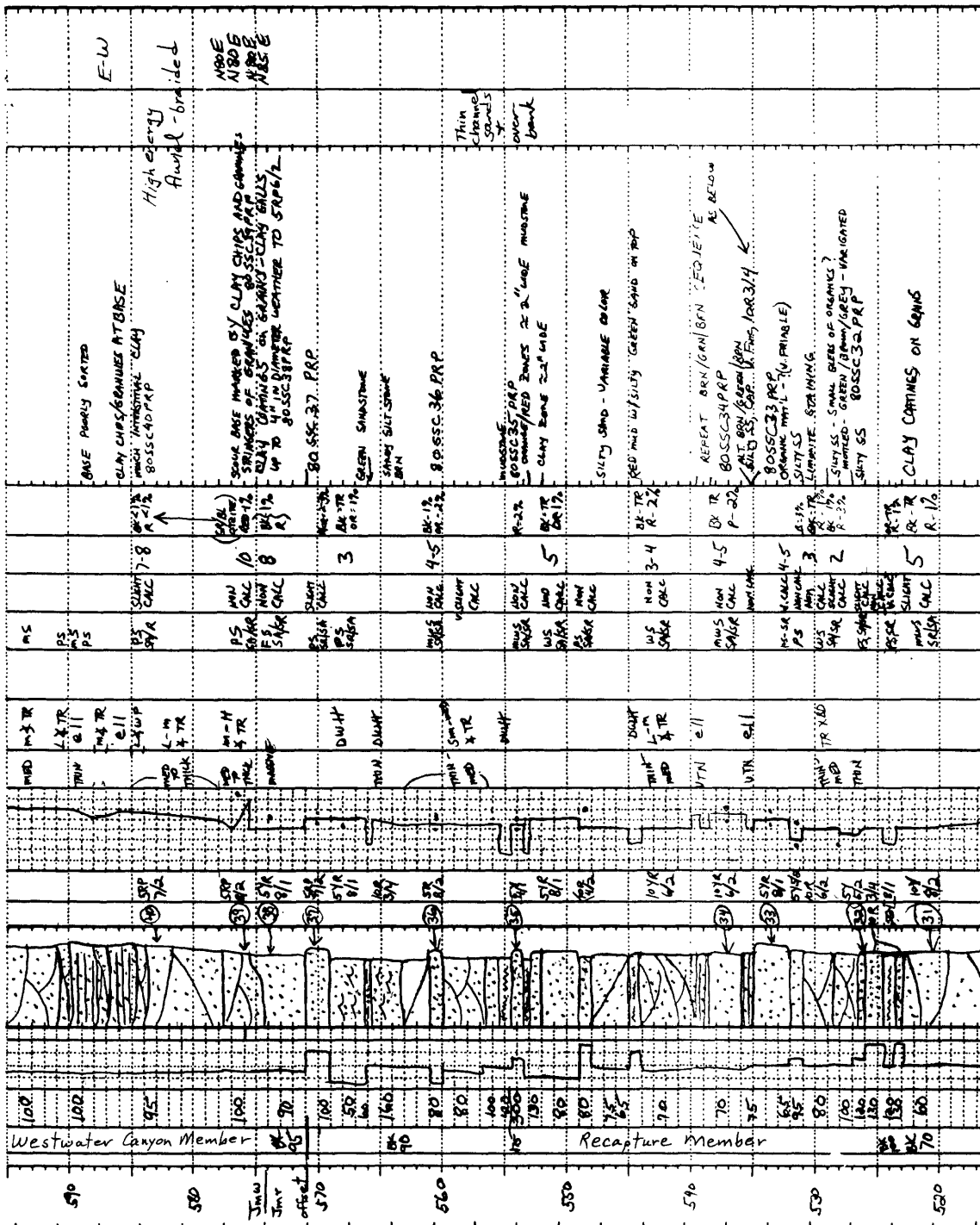
LOCATION PIPELINE ROAD Sec. 30 T. 26 N. R. 31 E. (est.)
 STATE Arizona COUNTY Apache
 U.S.G.S. CORE LIBRARY NUMBER API WELL NUMBER



API WELL NUMBER



LOCATION Pipeline Road Sec. 30 T. 26N R. 31E (est)
 STATE Arizona COUNTY Apache
 U.S.G.S. CORE LIBRARY NUMBER _____ API WELL NUMBER _____



API WELL NUMBER

10

$$F_{\text{avg}} = 14.1 \text{ N}$$

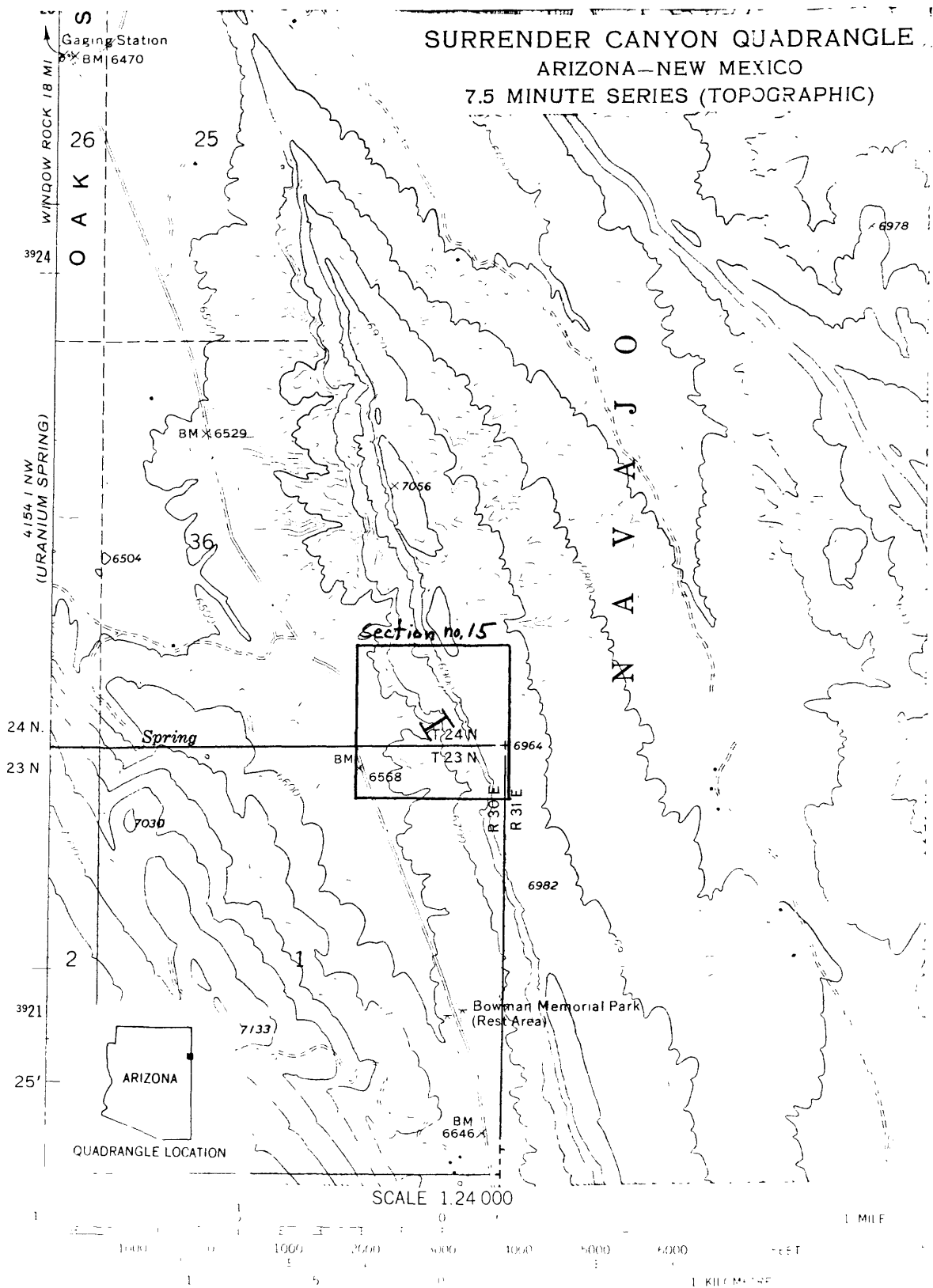
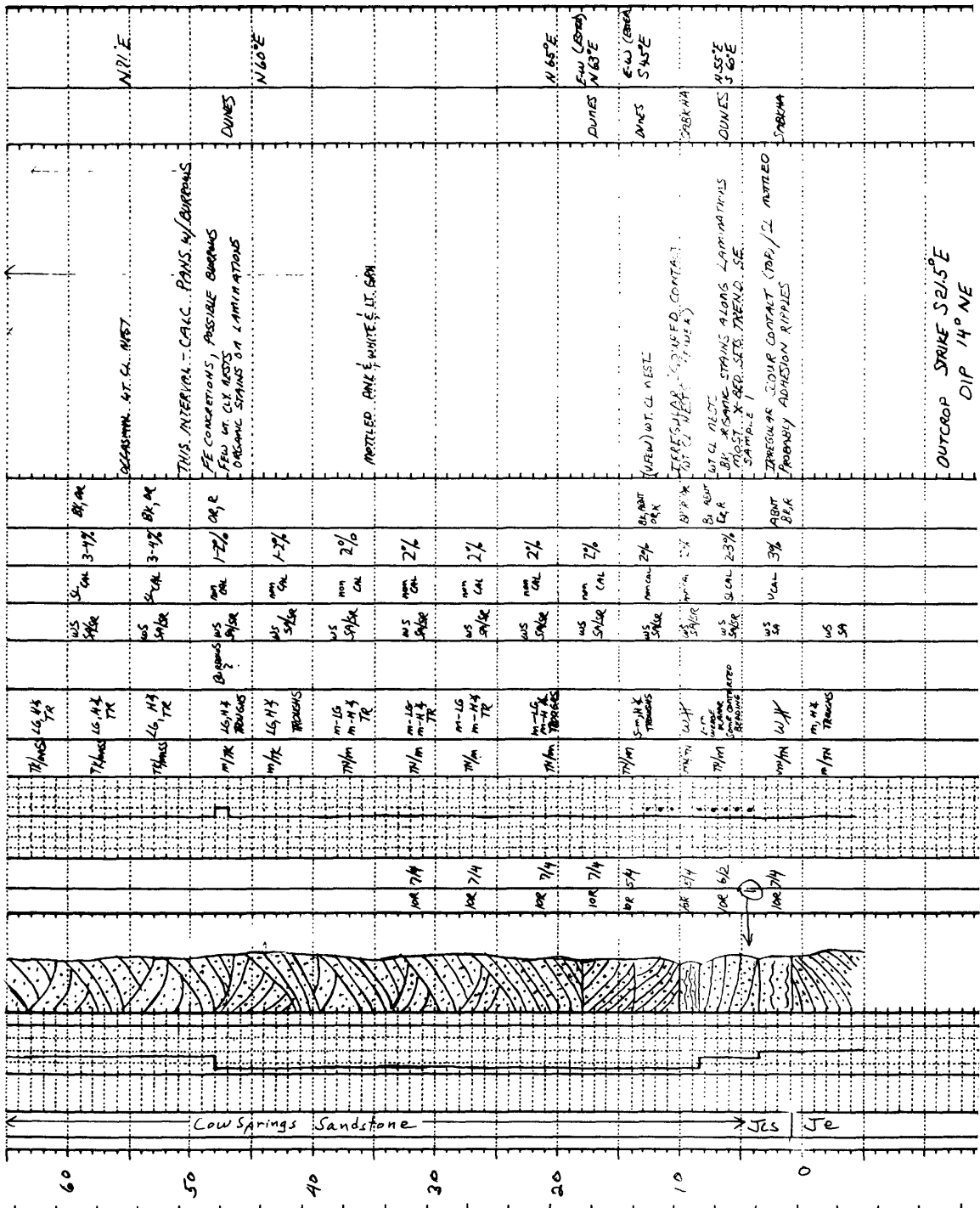
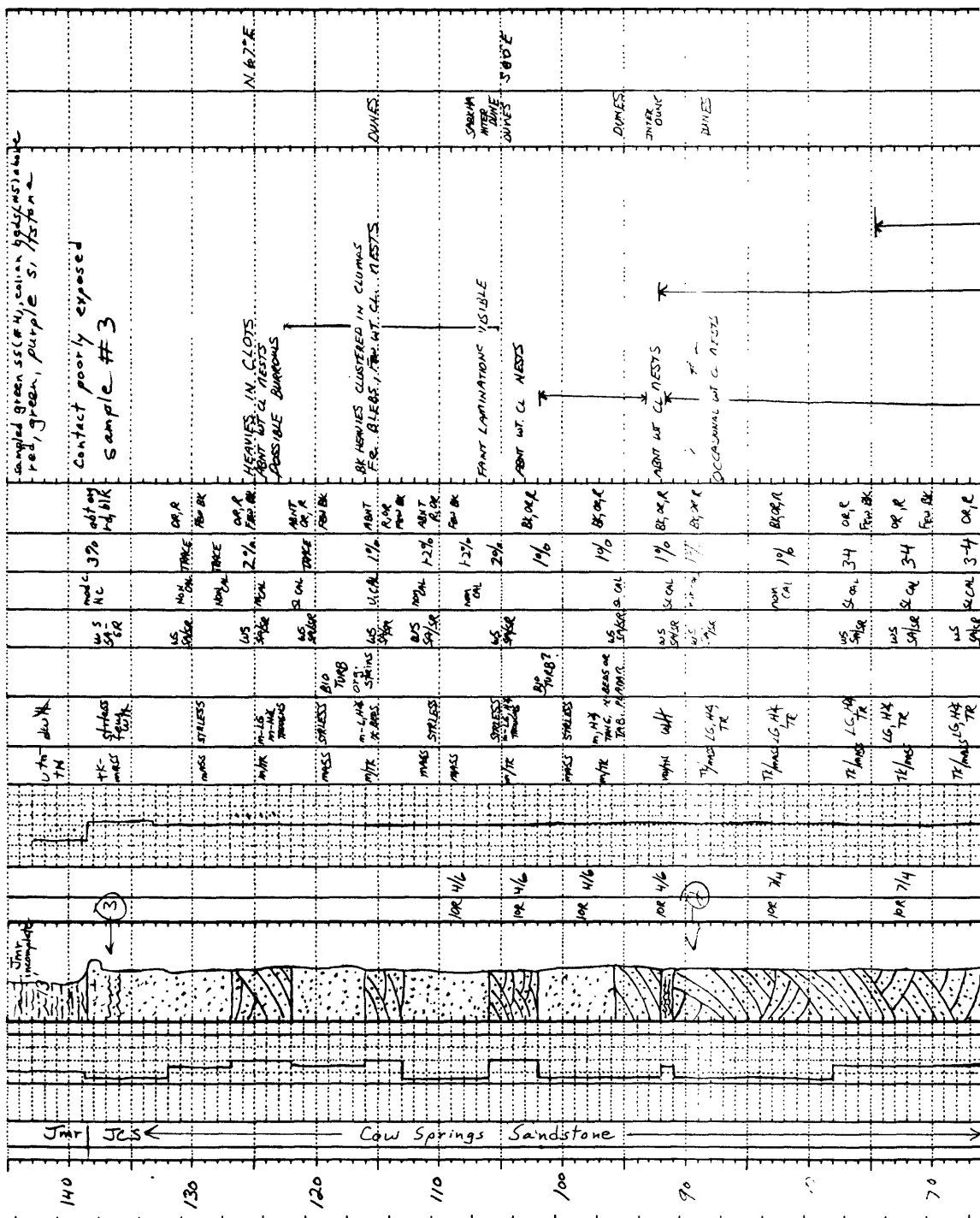


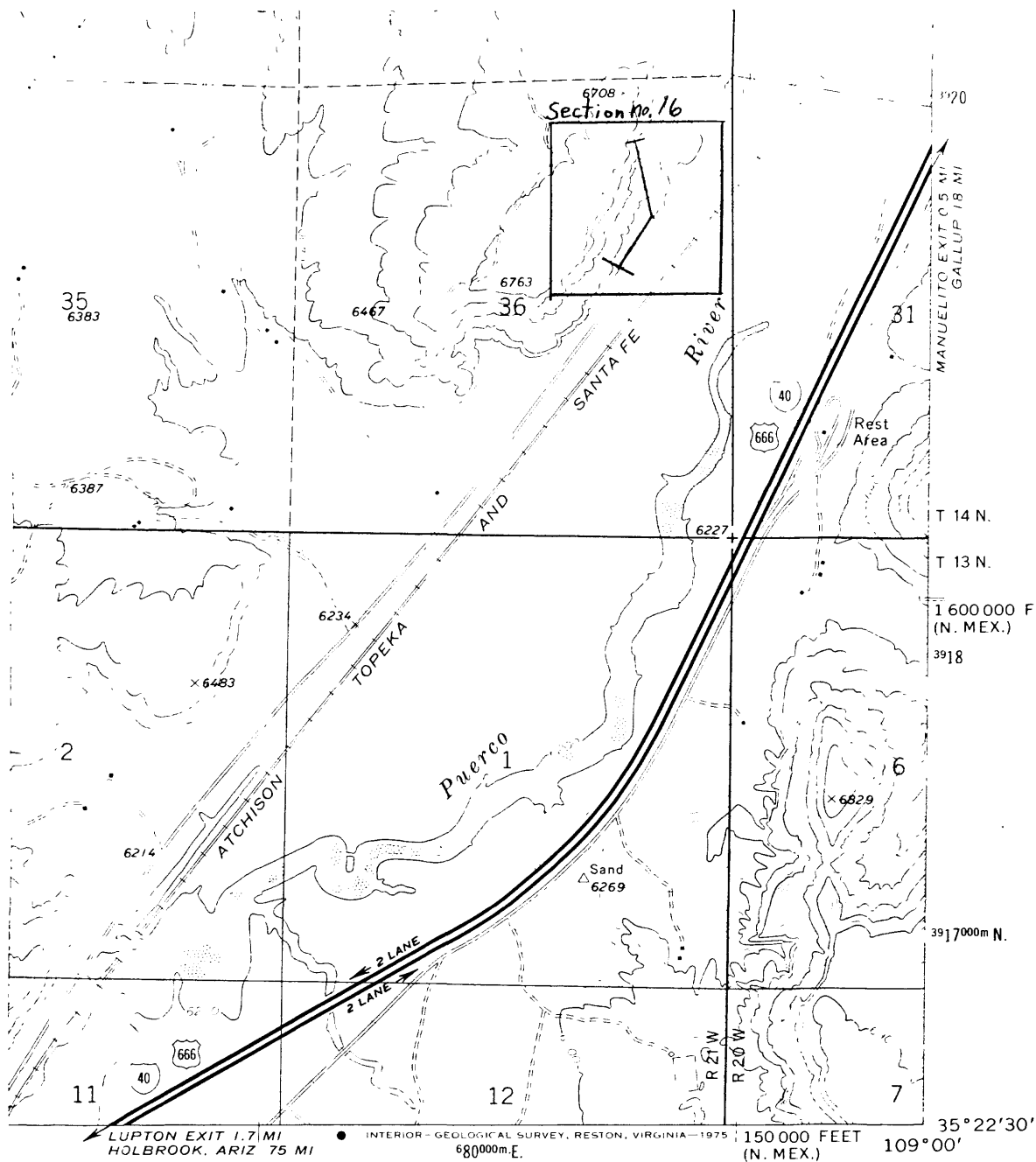
Figure 17. Location of measured section no. 15.

15. LOCATION BOWMAN PARK Sec. 36 T. 24 N. R. 30 E.
 STATE Arizona COUNTY Apache
 U.S.G.S. CORE LIBRARY NUMBER 8183 API WELL NUMBER CONORN, HARRIS



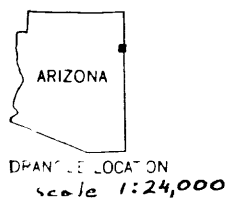
U.S.G.S. CORE LIBRARY NUMBER..... API WELL NUMBER.....





ROAD CLASSIFICATION

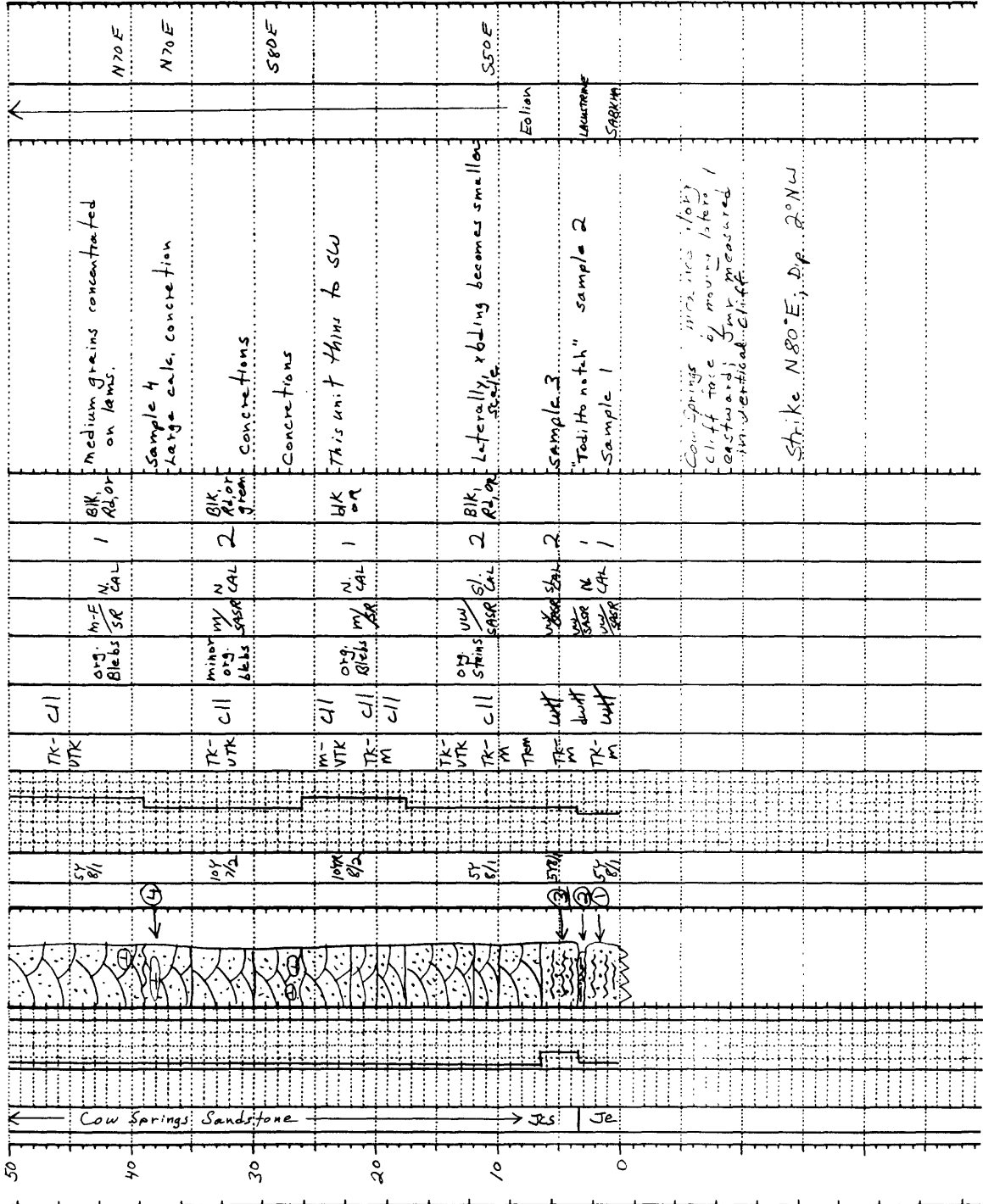
- | | | | |
|------------------------------------|-------------|--|--|
| Primary highway,
hard surface | | Light-duty road, hard or
improved surface | |
| Secondary highway,
hard surface | | Unimproved road | |
| Interstate Route | U. S. Route | State Route | |



SURRENDER CANYON, ARIZ.—N. MEX.
N3522.5—W10900/7.5

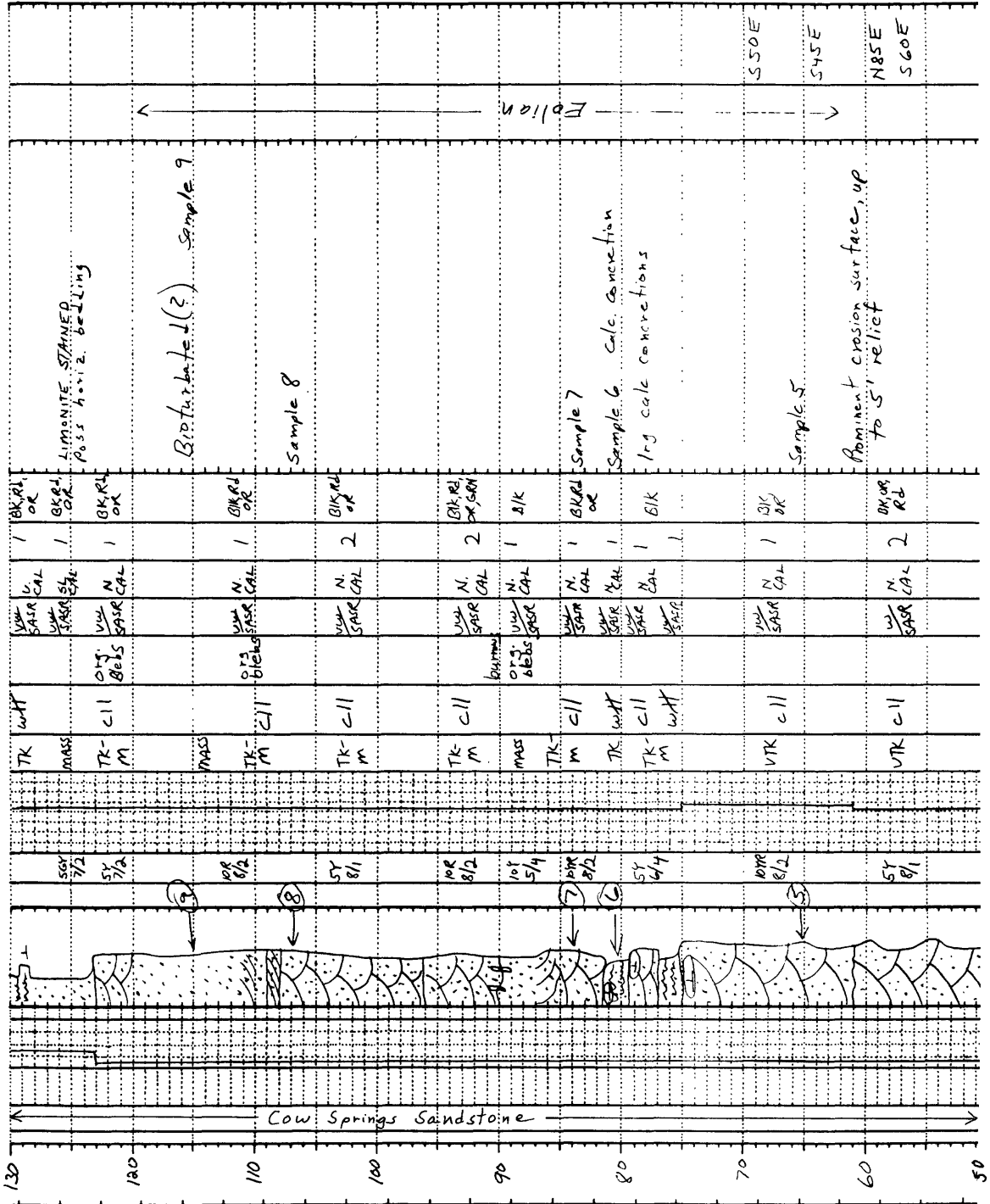
Figure 18. Location of measured section no. 16.

LOCATION ¹⁶Manuelito Sec. E 1/2, NE 1/4, 36 T. 14 N. R. 21 W.
 STATE New Mexico COUNTY Mckinley
 U.S.G.S. CORE LIBRARY NUMBER 8/82 API WELL NUMBER CONDOCH, HILDEBRANDT



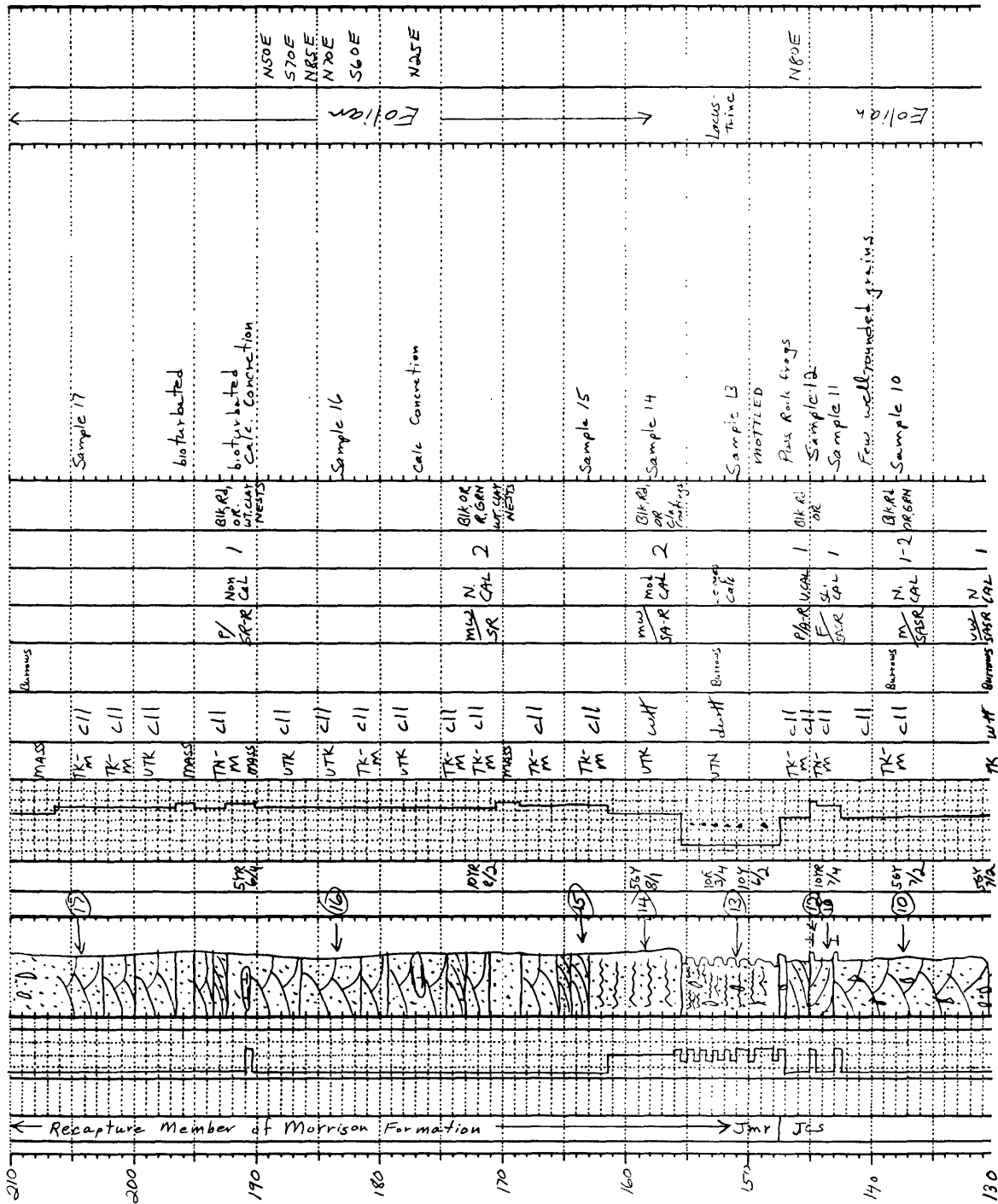
2

LOCATION ¹⁶Manuelito Sec. 36 T. 14N R. 21W
STATE New Mexico COUNTY McKinley
U.S.G.S. CORE LIBRARY NUMBER API WELL NUMBER



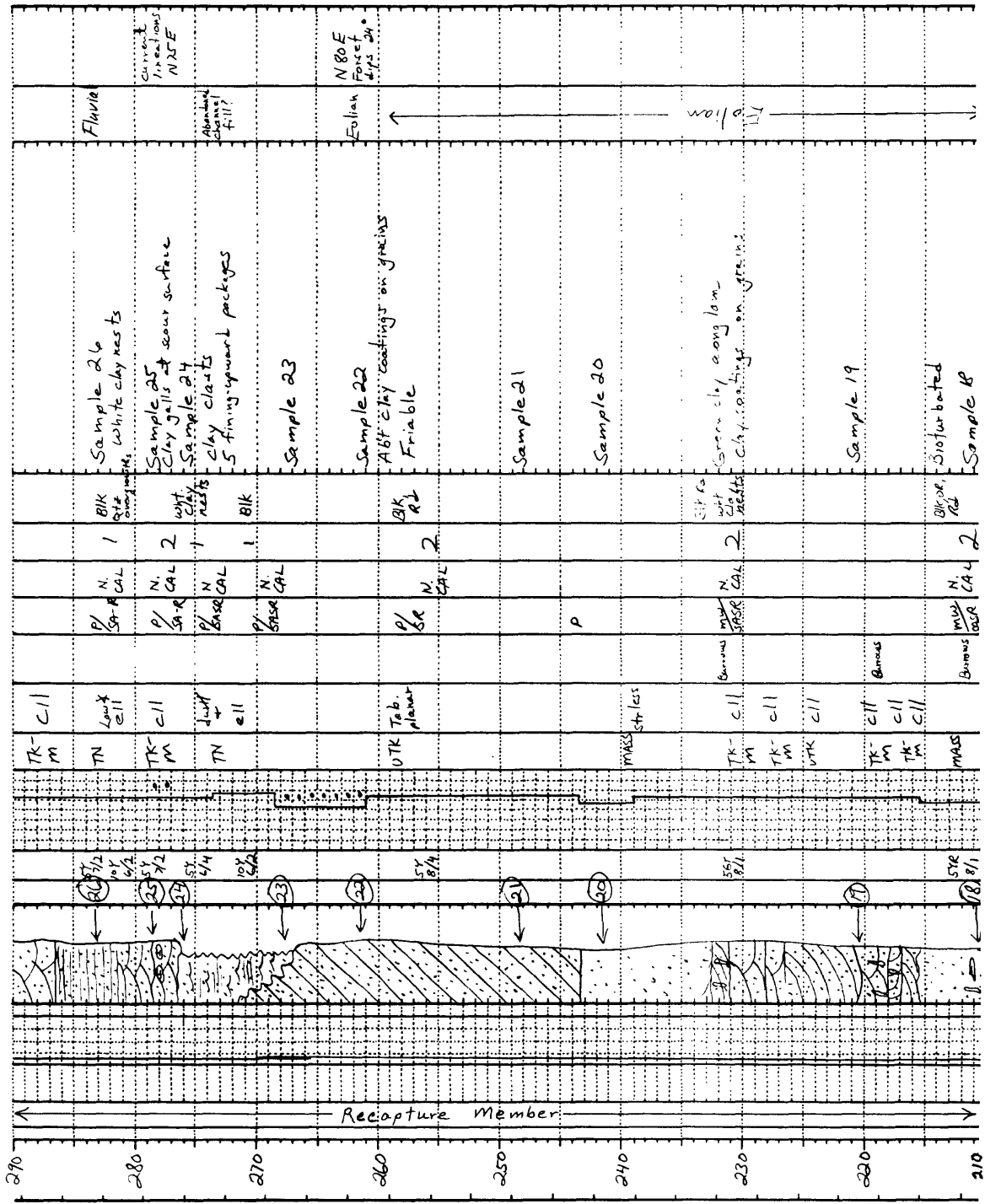
③

LOCATION Manuelito Sec. 36 T. 14N R. 21W
 STATE New Mexico COUNTY Makinley
 U.S.G.S. CORE LIBRARY NUMBER _____ API WELL NUMBER _____



④

LOCATION Manuelito Sec. 36 T. 14N R. 21W
STATE New Mexico COUNTY Mckinley
U.S.G.S. CORE LIBRARY NUMBER _____ API WELL NUMBER _____



5



⑨

LOCATION Manuelito Sec. 36 T. 14N R. 21W
 STATE New Mexico COUNTY McKinley
 LATITUDE AND LONGITUDE

DEPT AND FORMATION TOPS	SHOWS FRACTURES (Type, angle)	C.P. 2	VISUAL POROSITY Est	CORE	ROCK TYPE	FOOTNOTES	COLOR	DOMINANT GRAIN SIZE	BEDDING (as observed)	SEDIMENTARY STRUCTURES	BIOLOGIC CONSTITUENTS	MUMMIES	SORTING	BOUNDARIES	CEMENT	PERCENT FELDSPAR	ACCESSORY MINERALS OR FRAGMENTS	DESCRIPTION	INFERRED ENVIRONMENT OF DEPOSITION	TRANSVERSE SECTION
400					Kd Incomplete	4009			TK m	cll	Carbonaceous shale						clay fragments	9' above base of KT is bed of carbonaceous shale pet. med., pebble frag. 2" dia. Sample 40 v. abt clay matrix faint lams	Fluvial	
390						3911			TK m	cll								Abt white clay coatings on grains Sample 39		
380						3808			TK m	cll								Some blk grains alt to hematite clay nests Sample 38	Fluvial	N60E
370						3712			UTK m	cll								Coarse grains on lams Sample 37 clay coatings		N60E

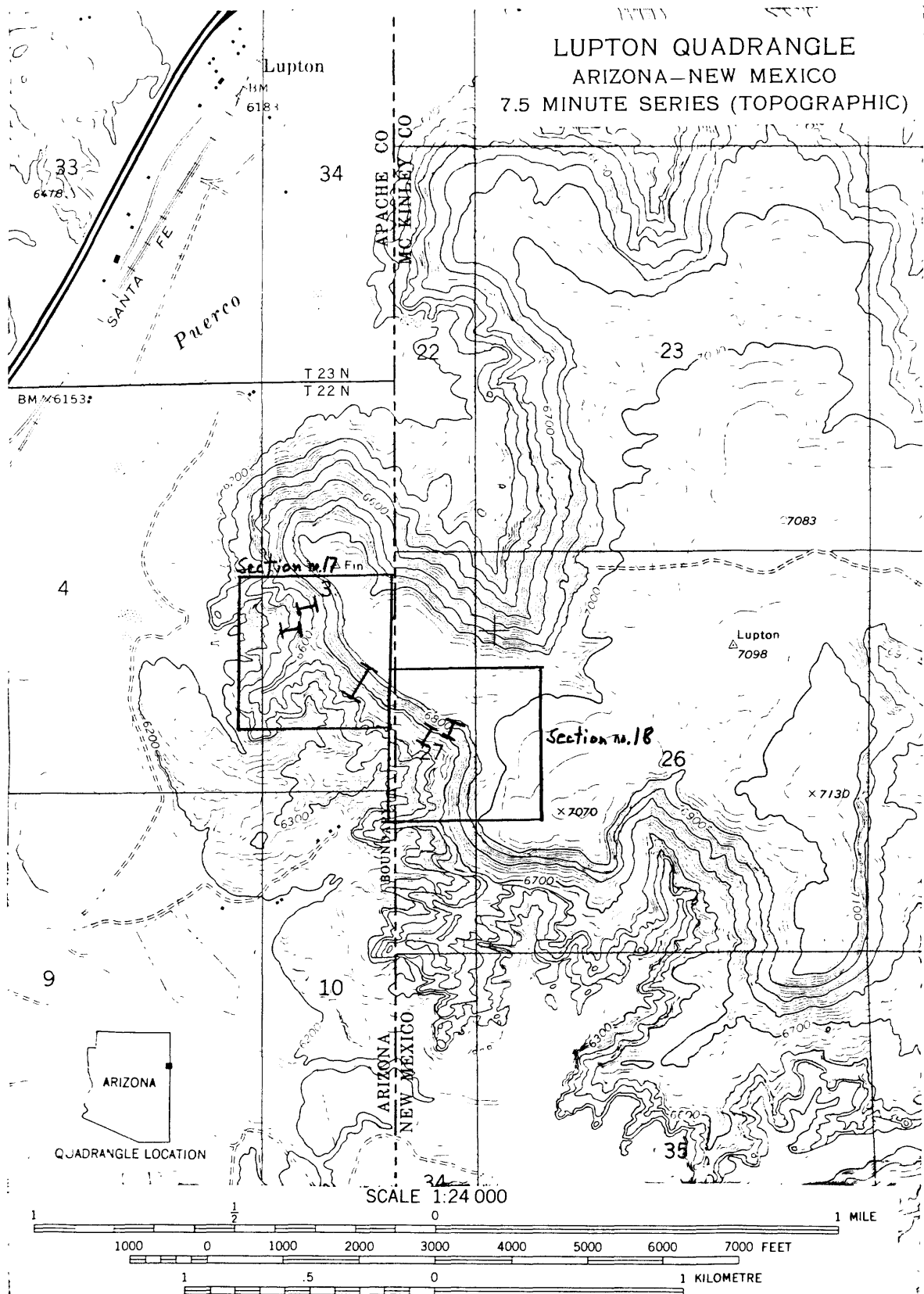
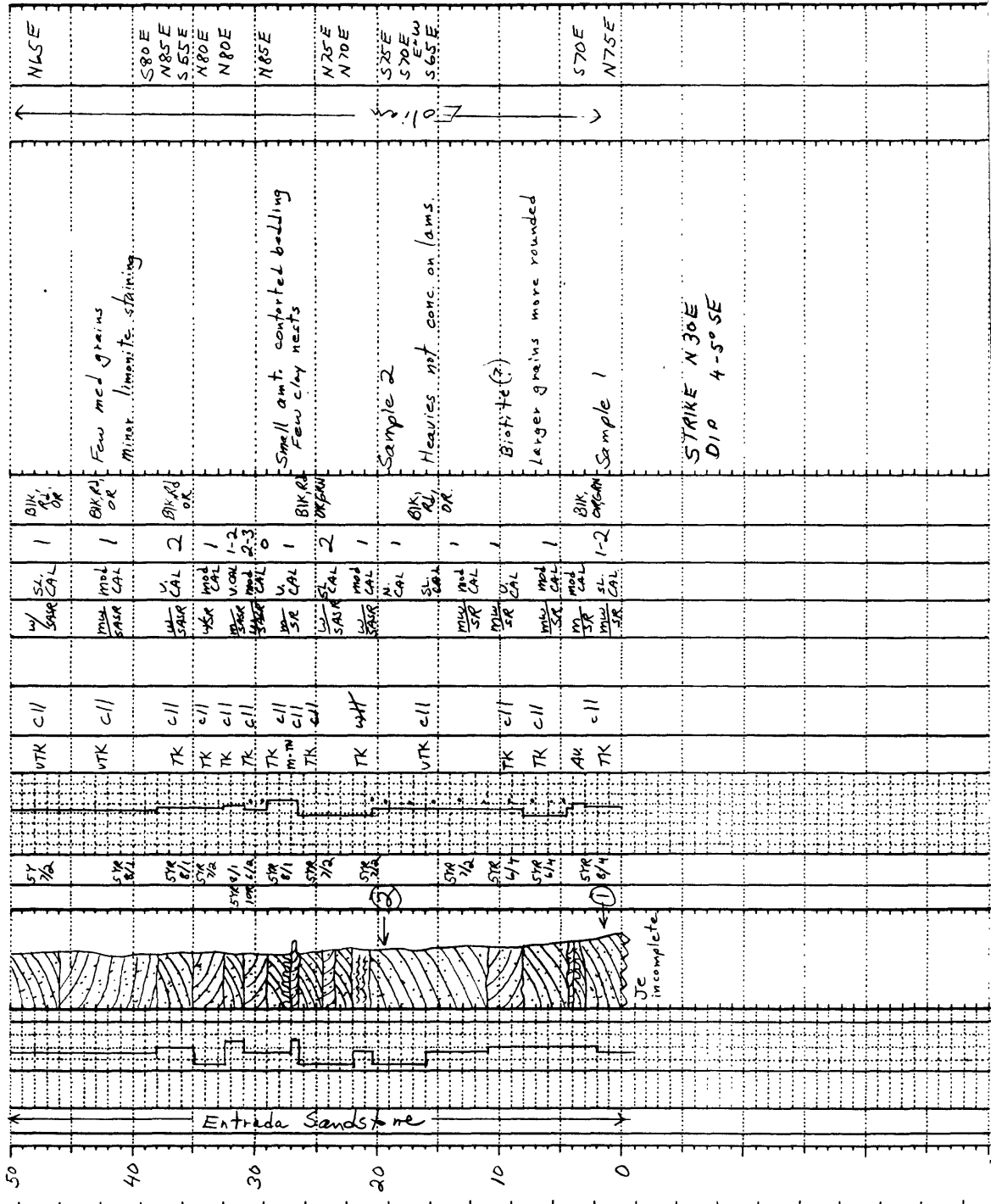
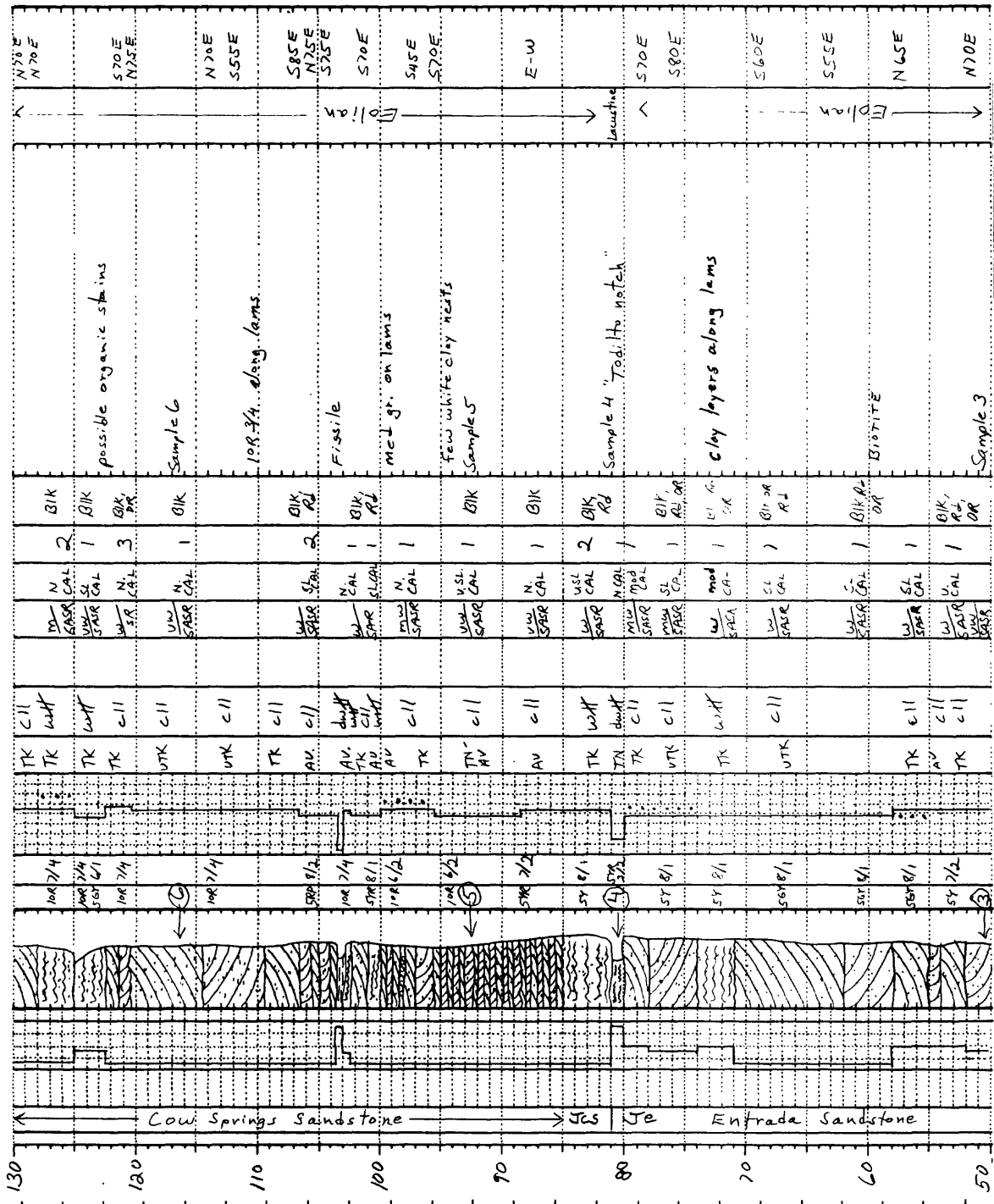


Figure 19. Location of measured section no. 17.

LOCATION ¹⁷ Lupton West Sec. N1/2, SW1/4 3 T. 22 N. R. 31 E.
 STATE Arizona COUNTY Apache
 U.S.G.S. CORE LIBRARY NUMBER 8182 API WELL NUMBER 20004, HUBBARD

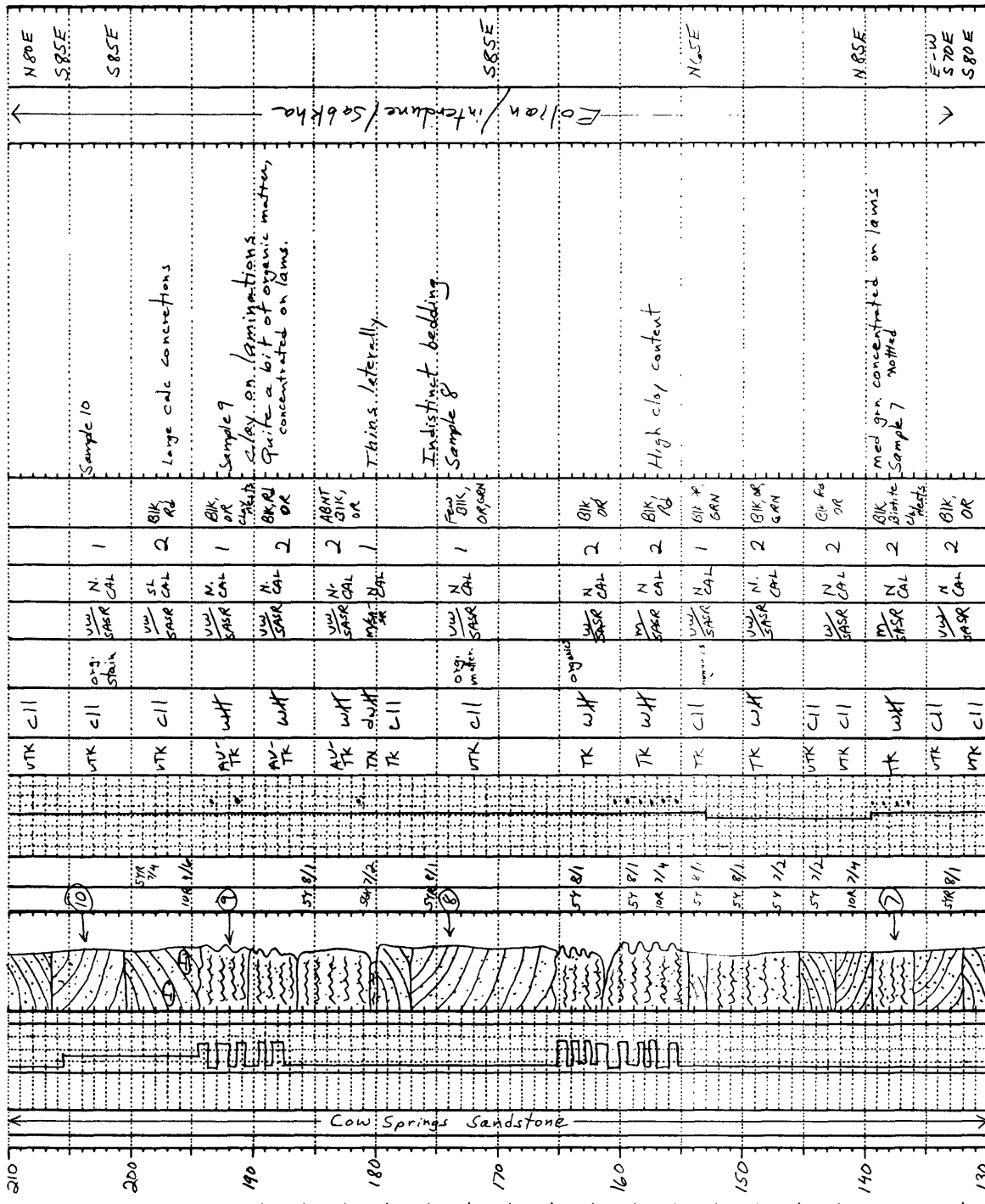


LOCATION Lupton West Sec. 3 T. 22 N. R. 31 E.
 STATE Arizona COUNTY Apache
 U.S.G.S. CORE LIBRARY NUMBER _____ API WELL NUMBER _____



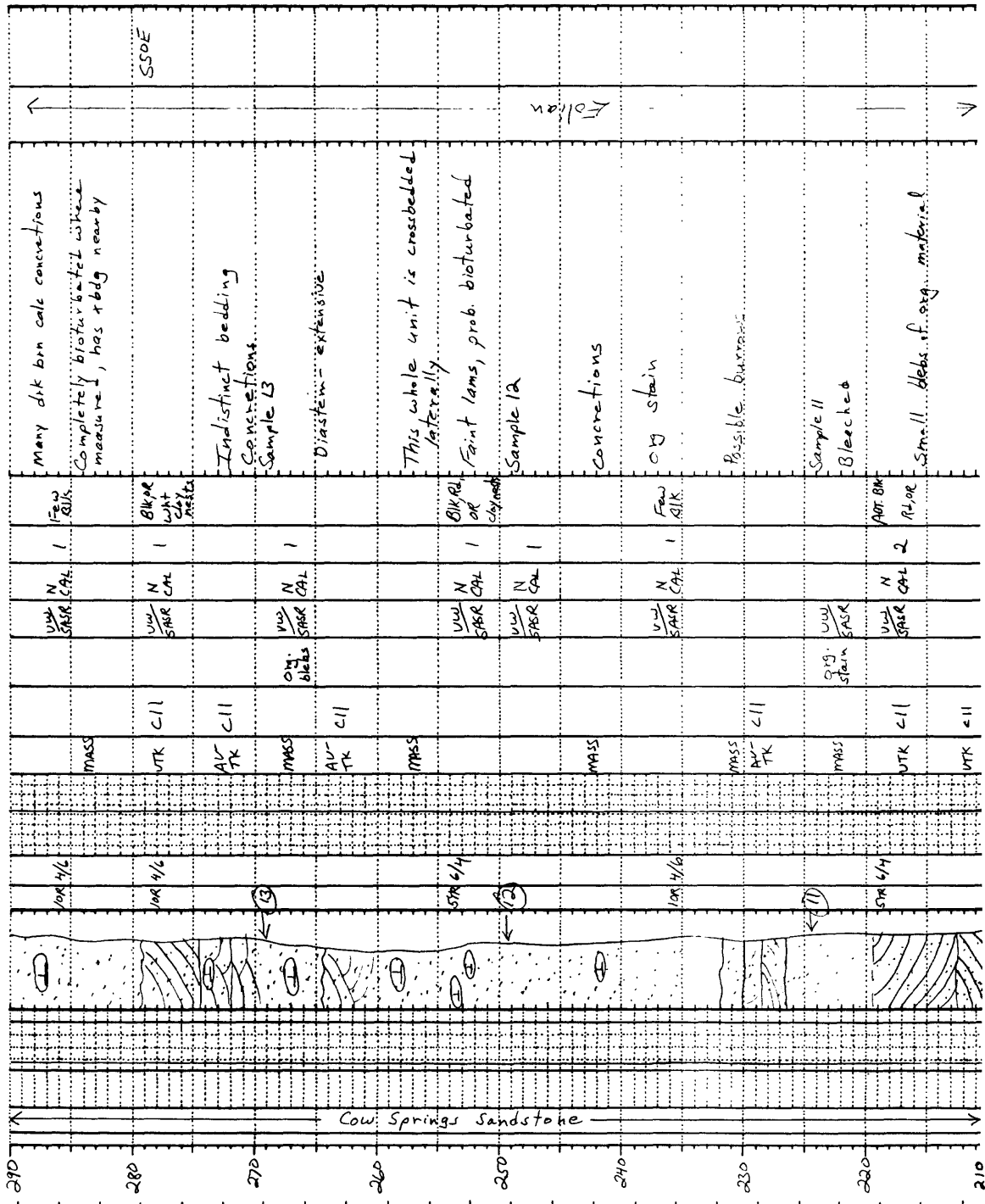
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LOCATION Lupton West Sec. 3 T. 22N R. 31E
 STATE Arizona COUNTY Apache
 U.S.G.S. CORE LIBRARY NUMBER _____ API WELL NUMBER _____



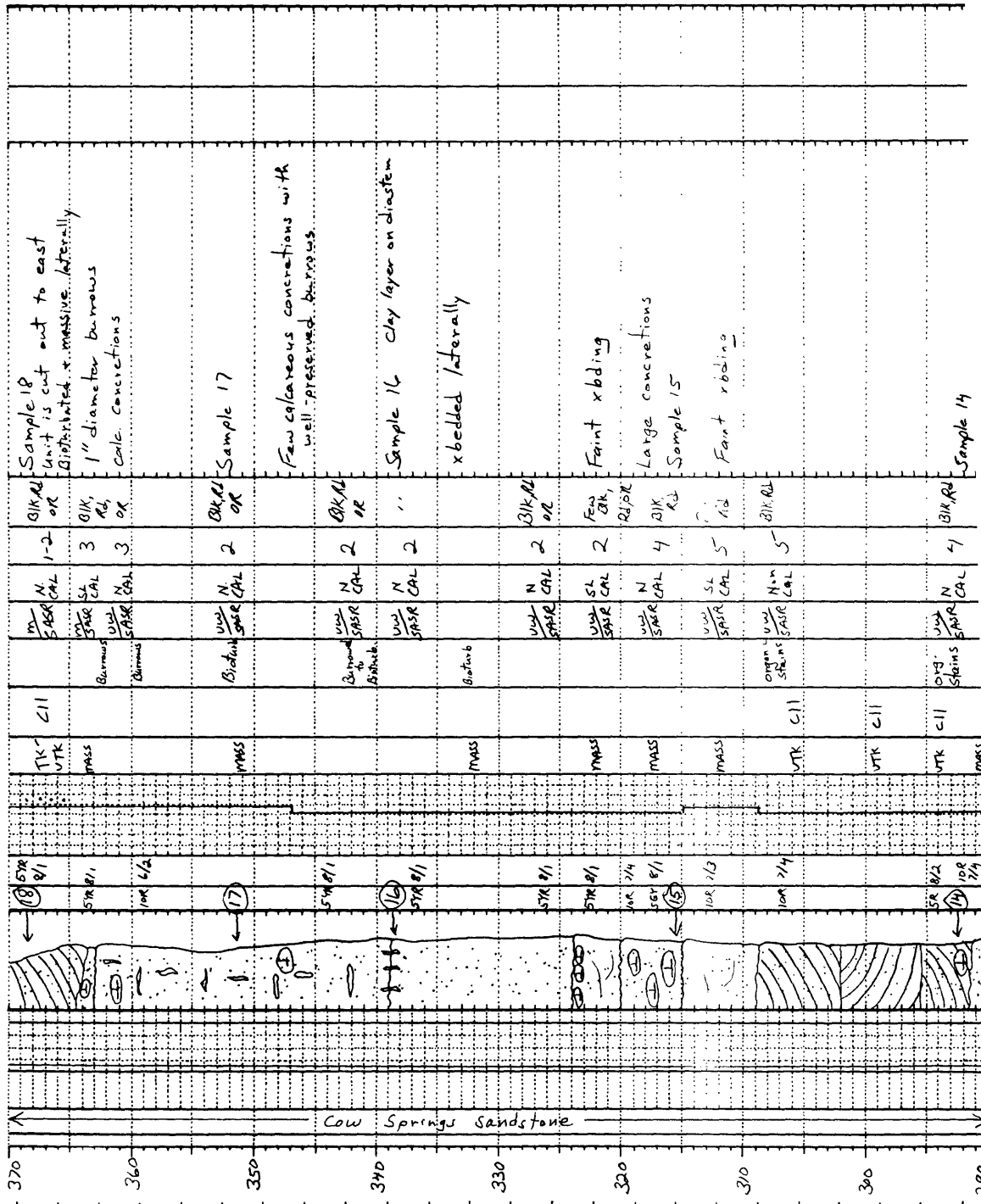
⑦

LOCATION Lupton West Sec. 3 T. 22N R. 31E
 STATE Arizona COUNTY Apache
 U.S.G.S. CORE LIBRARY NUMBER _____ API WELL NUMBER _____



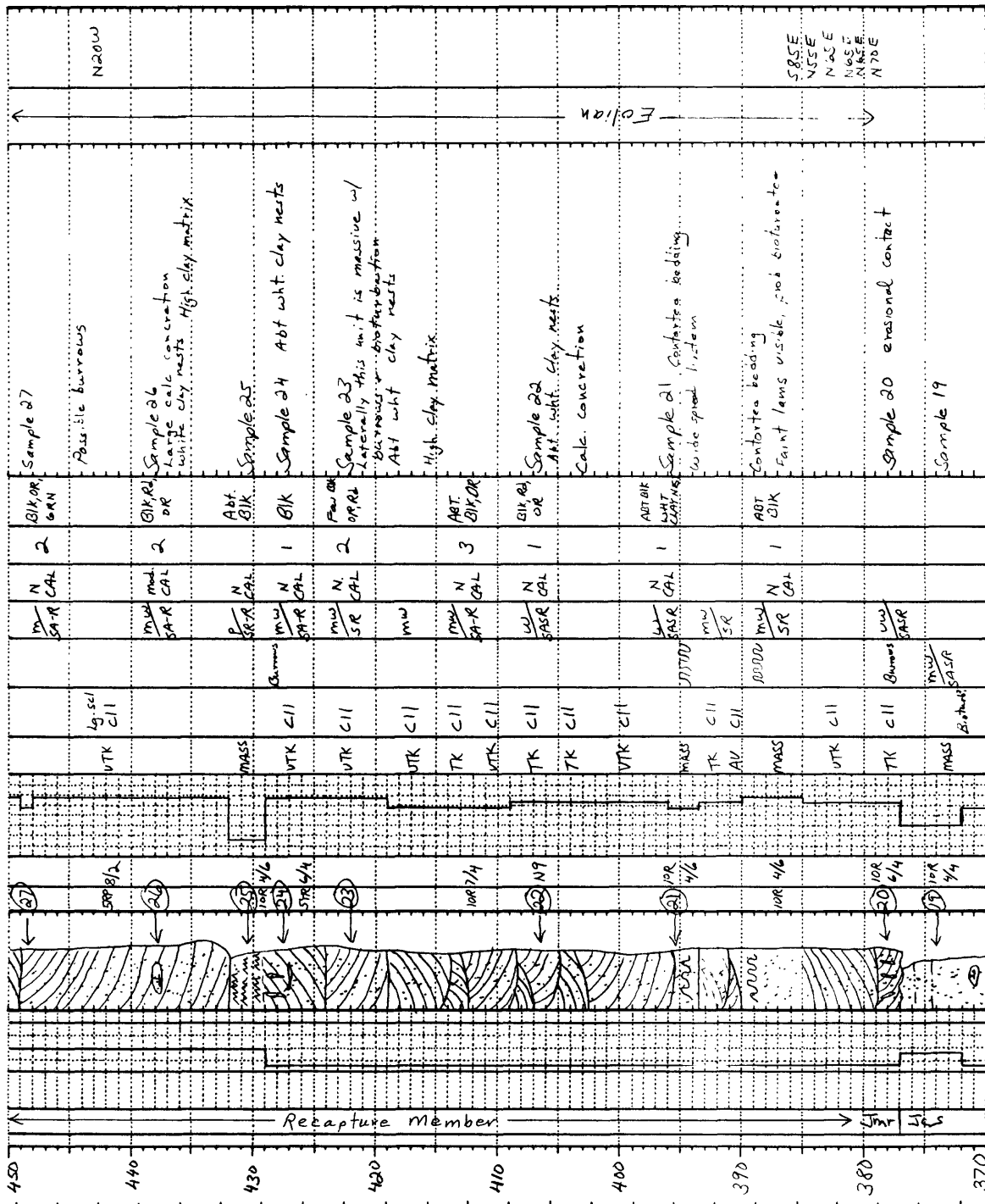
⑤

LOCATION Lupton West Sec. 3 T. 22N R. 31E
 STATE Arizona COUNTY Apache
 U.S.G.S. CORE LIBRARY NUMBER _____ API WELL NUMBER _____



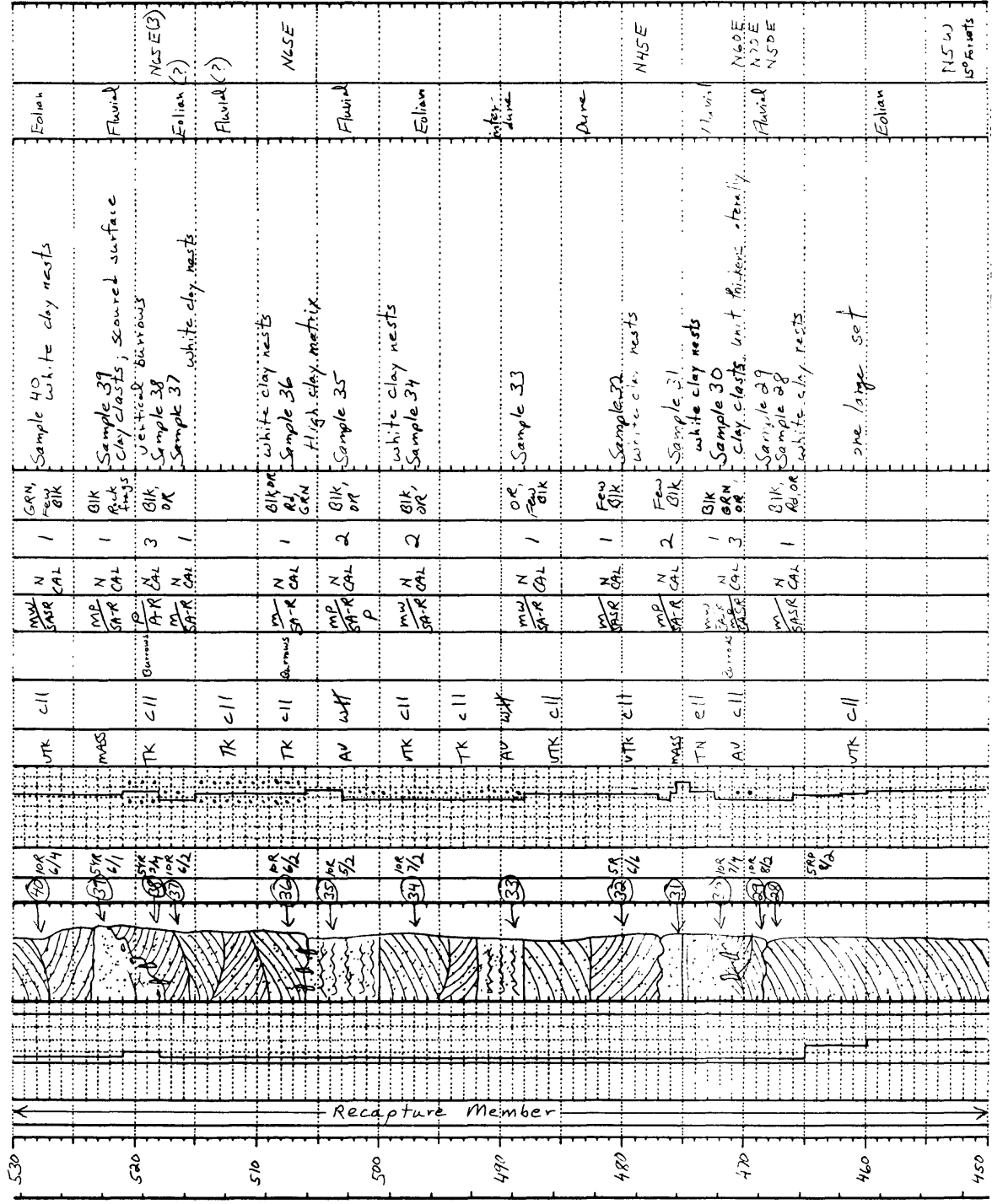
②

LOCATION Lupton West Sec. 3 T. 22N R. 31E
 STATE Arizona COUNTY Apache
 U.S.G.S. CORE LIBRARY NUMBER _____ API WELL NUMBER _____



⑦

LOCATION Lupton West Sec. 3 T. 22 N R. 31 E
 STATE Arizona COUNTY Apache
 U.S.G.S. CORE LIBRARY NUMBER _____ API WELL NUMBER _____



LOCATION Lupton West Sec. 3 T. 22N R. 31E
 STATE Arizona COUNTY Apache
 LATITUDE AND LONGITUDE

DEPT/ALT	FORMATION TOPS	SHOES	FRACTURES (typ. anglo)	C.P.S.	VISUAL POROSITY	CONC.	ROCK TYPE	FOOTNOTES	COLOR	CLAY DOMINANT	GRAIN	SIZE	BEDDING (as observed)	SEDIMENTARY STRUCTURES	BIOLOGIC CONSTITUENTS	MUDCRACKS	SORTING	CEMENT	PERCENT	ACCESSORY MINERALS OR FRAGMENTS	DESCRIPTION	INFERRED ENVIRONMENT OF DEPOSITION	TRANSPORT DIRECTION
570			Kd		Good		Kd incomplete	43		Clay	fine	fine	AV	cll			Basal Cal	-			45-50 ft Kd exposed at top of cliff		
560			Jmr		Good			44					UTK	Lg. s.s. cll			Basal Cal				clay clefts		
550			Recapture		Good			45									Basal Cal				Sample 42 white clay nests		
540			Member		Good			46					UTK	Lg. s.s. cll			Basal Cal				clay clefts		
530					Good			47									Basal Cal				Sample 41		

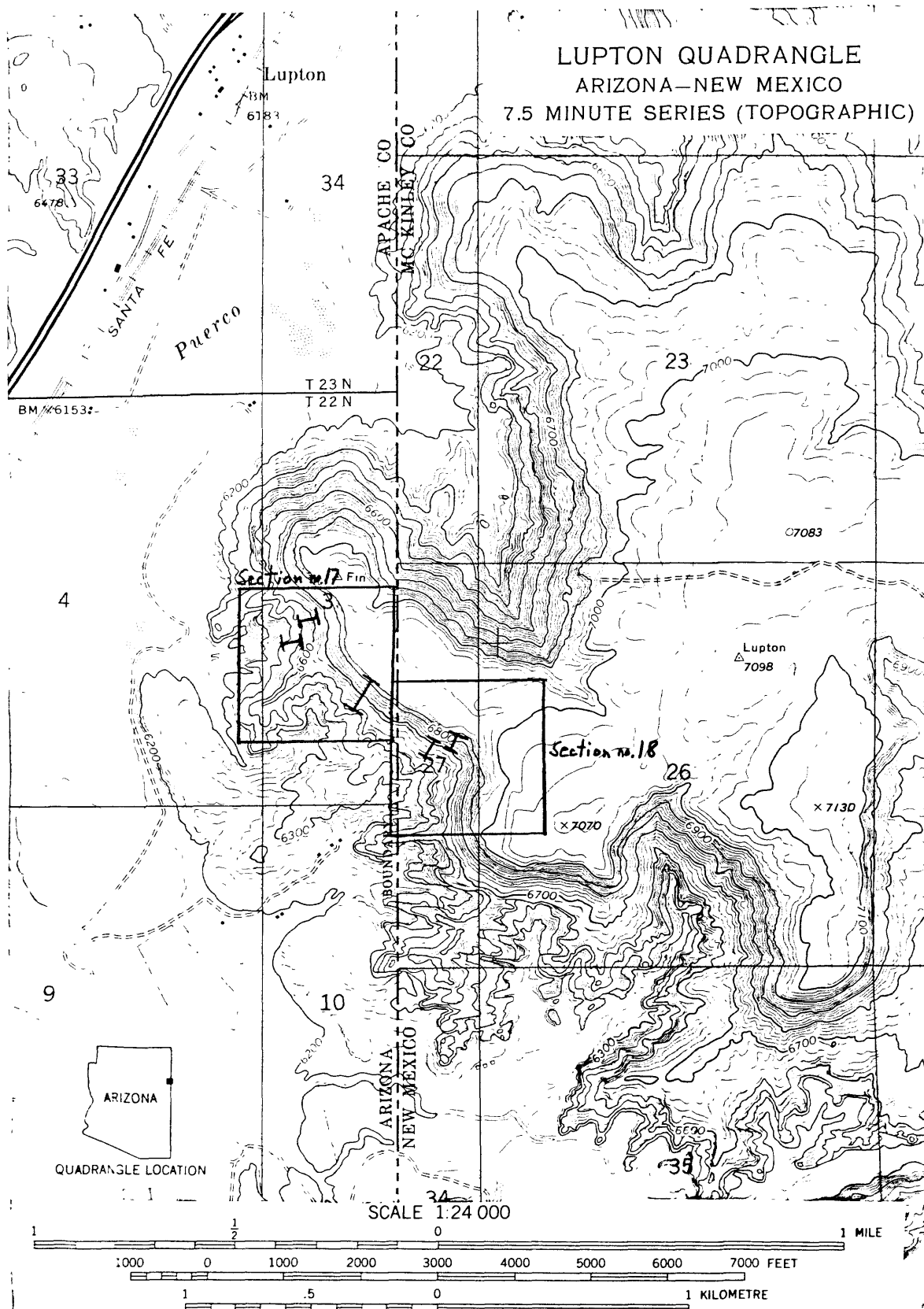
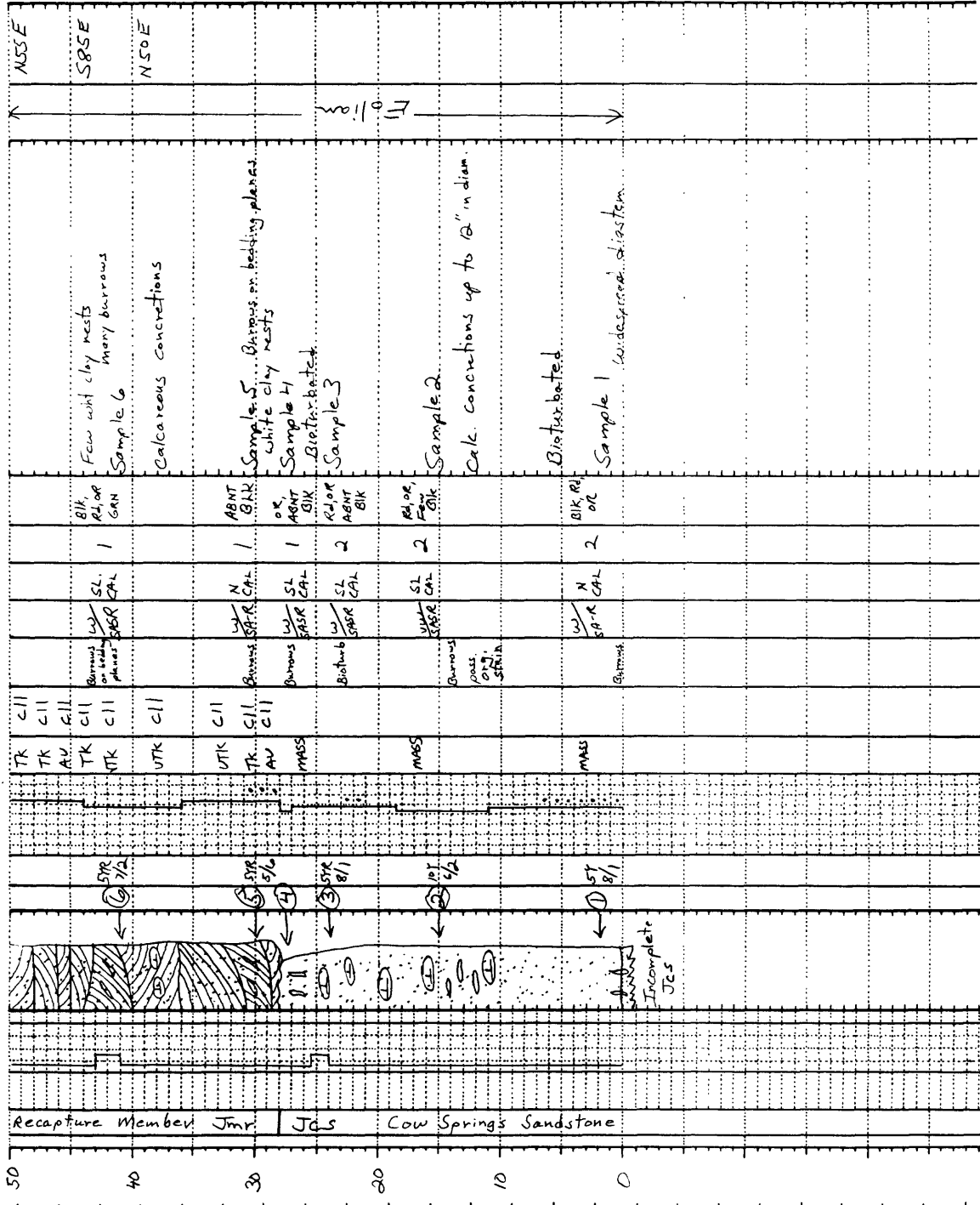


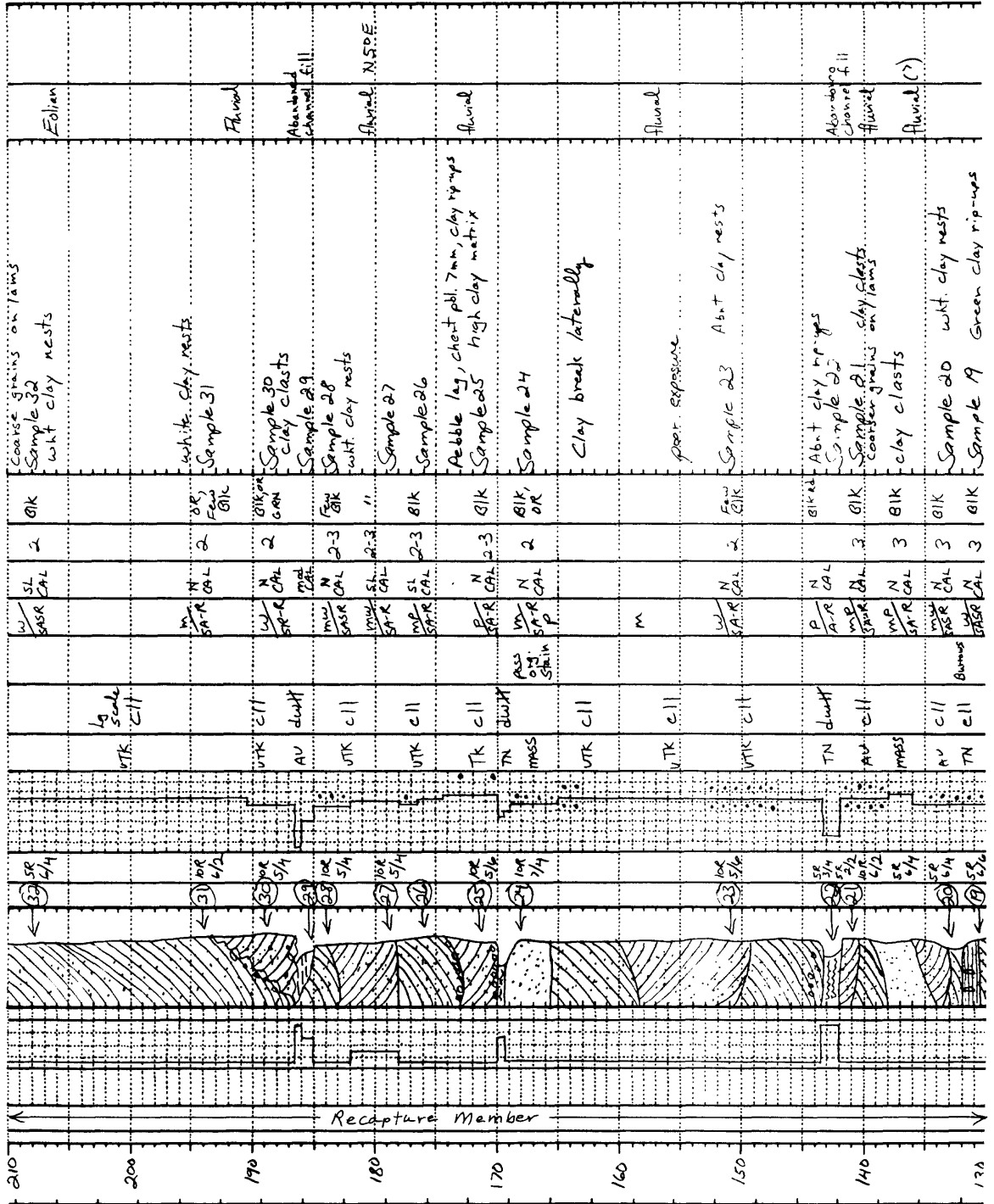
Figure 20. Location of measured section no. 18.

18.
 LOCATION Lupton East Sec. SE 1/4, NE 1/4, 27 T. 13 N. R. 21 W.
 STATE New Mexico COUNTY McKin.
 U.S.G.S. CORE LIBRARY NUMBER 8182 API WELL NUMBER CANBEN, HILDEBRANDT



3

LOCATION Lynton East Sec. 27 T. 13N R. 21W
STATE New Mexico COUNTY Mekinley
U.S.G.S. CORE LIBRARY NUMBER _____ API WELL NUMBER _____



Mckinley