NORTH DAKOTA GEOLOGICAL SURVEY
Wilson M. Laird, State Geologist

Geologic Report
on
Limestone Deposits
in
Stark County and Hettinger County, North Dakota

by
Miller Hansen

REPORT OF INVESTIGATION NO. 8
GRAND FORKS, NORTH DAKOTA
1953

REPRINTED 1958

NORTH DAKOTA GEOLOGICAL SURVEY

Wilson M. Laird, State Geologist

GEOLOGIC REPORT ON LIMESTONE DEPOSITS IN STARK COUNTY AND HETTINGER COUNTY, NORTH DAKOTA

by

Miller Hansen

Report of Investigation Number 8

1953

Reprinted 1958

Grand Forks, North Dakota

TABLE OF CONTENTS

	Page
ABSTRACT	2
A. INTRODUCTION	2
1. Acknowledgements	2
2. Purpose of the investigation	3
3. Previous work	4
4. Location of areas	4
5. Geography and Topography	5
6. Methods of study	6
B. GEOLOGY	7
1. Beds underlying the White River formation	7
2. Beds overlying the White River formation	8
3. The White River formation, general statement	8
a. Name and definition	9
b. Occurrence	9
c. Lithology	11
d. Thickness	12
e. Paleontology	12
f. Relation to adjacent formations	13
g. Correlations	13
h. Historical interpretation	13
C. PROBLEMS OF DEVELOPMENT	14
1. Problems of Quarrying	14
2. Availability of Fuel and Water	15
D. OVERBURDEN AND QUANTITIES OF LIMESTONE AVAILABLE	15
E. GEOLOGIC CONCLUSIONS	16
F. GENERAL DISCUSSION OF MAPPED AREAS	16
Appendix A Detailed location of areas	18
Appendix B General discussion of areas sampled but not mapped	19
Appendix C Logs of test holes	19
Appendix D Detailed Sections	22
Appendix E Comments on the Geologic Report by Oliver Bowles	29
Appendix F Natural Cement Possibilities by Oliver Bowles	30
Appendix G Bibliography	31

LIST OF ILLUSTRATIONS

Location Map No. 1
Location Map No. 2
Figure 1 Antelope Butte, geology and topography
Figure 2 Young Man's Butte, geology and topography
Figure 3 Antelope and Young Man's buttes, outline map of deposits, and geologic sections with analyses

Figure 4 Bull Butte, geology and topography
Figure 5 Bull Butte, outline map of deposits and geologic sections with analyses
Figure 6 Colgrove Butte, geology and topography
Figure 7 Colgrove Butte, outline map of deposits
Figure 7A Colgrove Butte, geologic sections with analyses
Figure 7B Colgrove Butte, geologic sections with analyses
Figure 7C Colgrove Butte, geologic sections with analyses
Figure 8 Long Butte, geology and topography
Figure 9 Long Butte, outline map of deposits, and geologic sections with analyses
Figure 9A Long Butte, geologic sections with analyses
Figure 9B Long Butte, geologic sections with analyses
Figure 10 School Butte, geology and topography
Figure 11 School Butte, outline map of deposits and geologic sections with analyses
Figure 12 Straight Butte, geology and topography
Figure 13 Straight Butte, outline map of deposits
Figure 13A Straight Butte, geologic section with analyses
Figure 13B Straight Butte, geologic section with analyses
Figure 14 Areal correlations of Tertiary sediments
Figure 15 Concrete, North Dakota, sketch map of test drilling, and sections with analyses

ABSTRACT

Areas of White River limestones of Oligocene age totaling approximately two square miles were mapped on seven buttes of southwestern North Dakota. The limestone beds and the intercalated calcareous clays were sampled and sections were measured at several outcrops on each butte. Samples were also obtained by test drilling on Colgrove, Long, and School buttes.

It is estimated that a total of 6,468,000 cubic yards of limestone varying from 50% to 88% in calcium carbonate content are available from the deposits on Colgrove and Long buttes. Total stripping of overburden required is estimated at 5,630,000 cubic yards.

In order to supplement previous sampling of Cretaceous beds, the Niobrara formation was sampled at two locations west of Walhalla in Pembina County.

The North Dakota Research Foundation made chemical analyses of all the samples to aid in determining whether the deposits might be used in the manufacture of cement.

INTRODUCTION

Acknowledgements

Dr. Wilson M. Laird, State Geologist and Head of the Geology Department at the University of North Dakota, supervised this investigation and contributed advice both on field procedure and in the

preparation of the report. Dr. Teng-Chien Yen, Research Geologist at the Smithsonian Institution, identified the Mollusca from the limestone beds. Mr. Nicholas Kohanowski, of the University of North Dakota's Geology Department, identified minerals from the basal sand. Mr. William E. Benson, Geologist of the United States Geological Survey examined geologic sections and contributed advice on formation contacts. George Lefor and Frank Cherney of Lefor, North Dakota, drilled the test holes, thus providing samples from areas where the beds could not be sampled from outcrops. Thanks are due the many landowners of the area included in the investigation, all of whom cooperated to the fullest extent.

Dr. Oliver Bowles, Consultant, of Washington, D. C., formerly Chief of the Non-Metallics Economics Division of the U. S. Bureau of Mines, was retained to review the geological work. A statement of his views will be found in appendices E and F in this report.

Purpose of the Investigation

The possibility of using the limestone beds of southwestern North Dakota for the manufacture of cement has been considered for many years. Accordingly, the State Legislature passed a law in 1951 directing the North Dakota Geological Survey to make a survey and investigation of limestone deposits in North Dakota, and to report on their findings to the North Dakota Research Foundation. The law (14) is quoted below:

CHAPTER 34

H. B. No. 720
(Bubel, Lillehaugen, Einarson and Link)

SURVEY, ETC., OF FEASIBILITY OF
NORTH DAKOTA CEMENT PLANT

AN ACT

Making an appropriation to pay for a continuation of the survey and investigation to determine the feasibility of establishing a cement plant in the State of North Dakota.

Be it Enacted by the Legislative Assembly of the State of North Dakota:

1. APPROPRIATION There is hereby appropriated out of any moneys in the state treasury, not otherwise appropriated, the sum of twelve thousand dollars, to pay for a complete survey and investigation of limestone deposits in North Dakota by the North Dakota Geological Survey. The state Geological Survey is diredted to report on their findings to the North Dakota Research Foundation which, in turn, will present a report covering the technical and economic features of the production of cement in North Dakota to the Thirty-third Legislature Assembly of the State of North Dakota, which report shall include all factors bearing upon the location of a cement plant, access to natural deposits needed for the manufacture and production of cement access to transportation facilities, cost of construction of the plant, the best type of production, marketing data, and any and all other information that will aid in determining the feasibility of establishing a cement plant.

Approved March 7, 1951

This investigation was undertaken to determine available yardages and quality of the limestone deposits, and to obtain additional information on the geology of the area. Later it was also decided to collect clay samples from outside the mapped areas to see if suitable deposits to add to a proper cement mix were obtainable.

Previous Work

In 1945 Powers (24) conducted an investigation of limestone deposits of Oligocene age in southwestern North Dakota. Powers mapped the limestone outcrop at several buttes and in the Killdeer Mountains, estimated available quantities of limestone, and sampled the limestone beds at various locations. He also sampled calcareous shales of Cretaceous age in the northeastern part of the state.

In 1947 the North Dakota Geological Survey supervised the drilling of five test holes in the Cretaceous shales near Concrete, Cavalier County, North Dakota. (See Figure 15) Samples were taken at two to three foot intervals and determinations for calcium carbonate were run by McMillan and Hoeppner of the North Dakota Research Foundation.

Samples from each hole, selected chiefly on the basis of a comparatively high calcium carbonate content, were analysed also for silica, iron, aluminum, magnesium, and sulfur. For the purpose of this report the determinations for calcium, silica, and aluminum are the only results tabulated. Figure 15 shows the location and top elevation of these test holes, and the analyses of selected samples.

In the drilling, gray and yellow clays were penetrated near the surface, and light to dark gray shales were found below the clays. (17)

In 1948 Thorsteinsson (28) mapped Colgrove Butte in Hettinger County, North Dakota, and estimated available limestone on the basis of his study of chemical analyses of samples for test holes drilled on the butte.

In 1949 the North Dakota Research Foundation published a report (8) in which the results of previous work are compiled, and which, in addition to deposits already mentioned, refers to investigations of marl deposits in the region south of Devils Lake. The conclusion is given that the deposits are too small and too low in quality to provide suitable material for the manufacture of Portland cement.

Location of Areas

Colgrove Butte, Bull Butte, and School Butte are located in Hettinger County, North Dakota. Antelope, Young Man's, and Long buttes are farther north in Stark County. Straight Butte is crossed by the Stark-Hettinger county line. The mapped areas are shown on Location Map No. 1. In addition to areas mentioned above, the Killdeer Mountains, the Little Bad Lands, the Hebron Brick Plant, and the areas near Dickinson from which clay samples were obtained are also shown on Location Map No. 1. Locations by township, range, and section for all the areas named are given in Appendix A.

The areas of test drilling near Concrete in Pembina County and the old Mayo brick plant in Cavalier County are shown on Location Map No. 2. Also shown on this map is the road cut location in Cavalier County from which a sample of cement rock was obtained.

Location of all these areas in the northeastern part of the state are given according to township, range, and section in Appendix A.

Geography and Topography

General Statement

The areas studied for this report, and thus the main areas of interest lie in Stark and Hettinger Counties. The two are essentially alike in climate and industry. Favorable crop conditions of the last several years have resulted in increasing acreages being plowed each fall, so that now some of the thin soils on top of the buttes have been seeded to grain.

Stark County

Stark County, with the county offices at Dickinson, is chiefly an agricultural area. Cattle are an important source of income, but there are relatively few sheep on the range.

The Northern Pacific Railroad and U. S. Highway No. 10 parallel each other in an east-west direction through the county. U. S. Highway No. 85 crosses the county from north to south at the extreme west end. State Highways 8 and 22 also cross the county from north to south, intersecting U. S. Highway No. 10 at Richardton and Dickinson respectively.

Simpson (27) describes Stark County as being practically free from glacial drift, with its moderately rolling topography and occasional higher buttes--the result of stream erosion. The county is drained by the Heart and Green rivers and their tributaries, and the drainage system is in an early mature stage of development.

The average annual precipitation (2) is 15 to 16 inches.

Hettinger County

The industries of Hettinger County, with the county offices at Mott, are also chiefly agriculture and livestock raising.

A branch line of the Chicago, Milwaukee, St. Paul, and Pacific Railroad enters the county near Bentley in the southeast corner and ends at New England in the northwest. A branch line of the Northern Pacific Railroad enters the county north of Bentley and terminates at Mott. State Highway 21 runs in a north-south direction near the western line of the county. State Highway 8 also crosses the county in a north-south direction.

Simpson (27A) states that the topography is of the rolling plateau type marked by high buttes, with a mature drainage system. The county is drained by Thirty Mile Creek and by the north and south forks of the Cannonball River.

The average annual precipitation like that of Stark County to the north is 15 to 16 inches.

Methods of Study

A telescopic alidade was used in mapping the areas investigated. Topographic maps with a contour interval of 20' were constructed on a scale of 1" to 660' with the exception of Young Man's and Antelope buttes which were mapped at 1" to 200'. Elevation at Colgrove, Bull, and Antelope Buttes were determined from the closest U. S. Coast and Geodetic Survey bench marks by means of a Paulin altimeter. At Long Butte and Young Man's Butte, elevations were taken from triangulation stations established on their summits by the U. S. Coast and Geodetic Survey. School Butte and Straight Butte were mapped from assumed datums.

Samples of limestone beds and the intercalated clays were taken from the outcrops at numerous points on each butte. The beds were sampled separately and the outcrops were measured at each location.

A cable tool rig was used to drill test holes at School, Long, and Colgrove Buttes. Most of the holes were drilled to a depth of twenty-five feet, but one hole on each butte was drilled into the sand-member, below which no limestone beds are found in the White River formation. Test holes were sampled at every foot below the top soil. The holes were bailed out after sampling at the foot mark and another sample was taken with the bailer when the next foot mark was reached. A log of the beds penetrated was kept on each test hole. See Appendix C for logs of these holes.

In addition to the samples taken for chemical analysis by the North Dakota Research Foundation a number of samples were duplicated in order to provide hand specimens.

Outcrop samples were also collected from the main ledges of sandy limestone in the Killdeer Mountains, and clay samples were obtained from the vicinity of Hebron, Dickinson, Lefor, and the Little Bad Lands district near South Heart.

The areas of the tops of the buttes were measured from the topographic maps by means of a planimeter, and the figures obtained were used in computing the yardage of limestone available from each butte.

Available yardages of limestone were computed on the basis of an average of the thickness of beds sampled and measured at each sample location. Yardages of clay were computed in the same manner. Only those beds assaying 50% calcium carbonate or higher were considered to be usable material.

GEOLOGY

Beds Underlying the White River Formation

Beds underlying the White River vary from place to place in the area investigated. (See Figure 14) At Antelope Butte the White River beds lie on 30 feet of yellow, brown, and purple-colored clays with shaly layers containing fossil wood, iron oxide concretions, thin-one to two inch seams of carbonaceous matter, and very fine grained sands. This bed appears to correspond to the typical basal "marker" bed of the Golden Valley formation of Eocene Age as described by Benson and Laird (5), and by Benson (3).

At the base of these clays, and exposed only at the north-west end of Antelope Butte, there is a layer of hard, brown-weathering sandstone 6' thick, which is fine grained, micaceous, calcareous, and shows cross bedding. This sandstone ledge is believed to represent the top of the Tongue River formation of Paleocene age in this area. Clinker is found to the north and west, near the base of Antelope.

At Young Man's Butte gray, yellow-brown, and red clays below the White River beds are believed to belong to the Golden Valley formation. On the lower slope to the south are several silicified stumps which indicate Tongue River beds though there are no good exposures.

At Long Butte there are several good exposures below the White River beds. Starting in a new (1951) road cut on the north line of Section 18, T. 137N., R. 94W., and proceeding toward the southwest into Section 13, T. 137N., R. 95W., the following section was measured. At the bottom of the drainage ditch on the south side of the road there is a very fine grained, yellow, uncemented sand. The bottom of this Golden Valley section lies at the top of this sand bed.

Top

4. Clay, yellow to gray, sandy with very thin carbonaceous seams, oxide concretions and seams, micaceous, faintly calcareous. Contains silicified wood, plant fragments in silicified siltstone, and small, 3/8" diameter, calcareous, sandy concretions. In upper portion large (6' + diameter) faintly calcareous sandstone concretions are numerous . . . . 36'+

3. Clay, black to brown, high in carbonaceous matter, becoming soft and soot black in top 6", sharp contact with bed above. . . . 1'2"

2. Clay, plastic, non-calcareous, gray with various shades of yellow and brown, 6" of yellow-brown-purple clay at top, grades into overlying bed. . . . . 3'6"

1. Sand, very fine grained, yellow, uncemented.

The upper portion of this section corresponds to the younger unnamed member of the Wasatch formation mentioned by Seager (26) which is the Golden Valley formation of Benson and Laird (5).

At School Butte the light-colored clays of the Golden Valley are exposed near the base of a short ridge at the southwest end and on the south slope of the butte where a small earth-fill dam has been built.

On Colgrove Butte at sample station 2 (see map Figures 7 and 7A) the base of the White River rests upon three feet of gray-green non-calcareous shaly clay which grades sharply downward into more than thirty feet of gray and white fine-grained, poorly cemented sandstone. The gray-green shaly clay is six feet thick at sample station 9 and changes color downward to drab yellow and brown, and dark purple. These beds appear to be typical Upper Tongue River as described by Leonard (18) and later by Benson (4).

Under the White River beds at sample station 32 on Bull Butte just west of Colgrove Butte there is a bed of clay five and one-half feet thick which is non-calcareous and varies in color from gray to yellow and green. Below the clay is a sand bed more than twenty feet thick which is very fine-grained, uncemented, light brown in color with a faint greenish cast and contains silt, and limonite concretions. Sandstone concretions are found in large irregular blocks. These beds, like those underlying the White River beds on Colgrove Butte, appear to be typical Tongue River, described by Seager (26) as Sentinel Butte, but now thought by Benson (4) to be Tongue River. Brown (6) demonstrated that the Sentinel Butte grades both laterally and vertically into Tongue River.

Leonard (18A & 20) described Fort Union beds in North Dakota before the introduction of the term Tongue River. Leonard included in the Fort Union formation the Triceratops-bearing Hell Creek beds of Cretaceous age at the base, and the fire and pottery clays of the Golden Valley formation at the top.

The beds now referred to the Tongue River formation are the middle and part of the upper division of the Fort Union as described by Leonard.

Beds Overlying the White River Formation

There are no beds above the White River in the area investigated. Pebbles found on top of the grass and at the grass roots on School Butte and Colgrove Butte are chiefly of chert and jasper, but a few are composed of a very fine-grained light-yellow quartzite. Specimens range in size from 1 to 6 centimeters greatest diameter and in shape from angular to rounded. Some of the chert pebbles are highly polished and many have pitted surfaces probably due to wind action. They vary widely in color, yellow and gray being most common, while a few are red or black. The sources of these pebbles is not known but it has been suggested in a personal communication from Dr. Wilson M. Laird that they may be related to the Oligocene Cypress Hills gravels of Saskatchewan, or to the Flaxville gravels of Montana. Alden (1) correlates some of the higher buttes in southwestern North Dakota with the Cypress Plain in Saskatchewan. Collier and Thom (10) believe the Flaxville gravels to be Miocene or Pliocene age. Both gravels consist chiefly of quartzites and argillites.

White River Formation

General Statement

The limestone beds are invariably found at or near the surface, capping all the buttes investigated. In many instances residual limestone fragments are found at the grass roots; and broken, jointed, well-weathered limestone beds from four to ten inches thick at the grass root are common. Where limestone is absent at the surface, a calcareous clay usually is found beneath the top soil. The limestones are found to be intercalated with and underlain by beds of calcareous clay. The clays become less calcareous with depth until they become non-calcareous or else give a very faint reaction with hydrochloric acid. In every area with which this report is concerned, a sand member was found at the base of the formation.

Graphical determinations using data from Bull, Colgrove, Long and School buttes show the local dip to be low and toward the northeast. At School Butte the dip is about twenty feet per mile and it is very likely that this figure is a good approximation for the other areas. Computations for the whole area, including Young Man's and Antelope Butte, show the dip to be toward the southeast. No computations for local dip were made on the latter two buttes since the top areas are small and the elevations on the beds vary but little.

Name and Definition

In 1857 Meek and Hayden (21) used the name White River for deposits at the summits of hills on the east side of the Missouri near the mouth of the White River in south central South Dakota. In 1862 Meek and Hayden (22) applied the name White River to 1000'+ of light colored clays with some sandstone beds and local limestones in the White River Badlands of South Dakota.

In 1882 White (31) discovered fish fossils on Sentinel Butte in beds which he assigned to the Green River group of Eocene age. In 1908 Leonard (18B) stated that these beds could probably be assigned to the White River formation.

In 1883 Cope (11) collected Oligocene fossils from a locality in North Dakota and described beds presumed by Leonard (18C) to be those of White Butte in southern Billings County. Since Leonard's report of 1908, southern Billings County has been changed to Slope County. A part of Cope's description follows: "The beds, which are unmistakably of the White River formation, consist of greenish sandstone and sand beds of a combined thickness of about 100 feet. These rest upon white calcareous clay, rocks, and marls of a total thickness of 100 feet. These probably also belong to the White River epoch, but contain no fossils."

Cope's was the earliest reference found, in which beds in North Dakota were definitely assigned to the White River formation.

In 1905 Douglass (13) also found Oligocene fossils at White Butte and discovered another area of White River (18D) beds in Stark County, twelve to sixteen miles southwest of Dickinson. These beds are found in what is called the Little Bad Lands district.

Occurrence

In 1922 Leonard (19) compiled information on exposures of White

River sediments known in the state at that time.

Areas that Leonard included are given below.

Area	Location
Little Bad Lands	S. W. Stark County six to eight miles south of South Heart.
White Butte	S. E. Slope County six to nine miles south of Amidon.
Bowman County	T. 131 N., R. 103 W., Section 20 Six to seven miles southeast of Rhame
Grant County	Capping three buttes in Northern part of T. 131 N., R. 90 W. and Southern part of T. 132 N., R. 90 W.
Sentinel Butte	Golden Valley County two miles south of the town of Sentinel Butte.
Killdeer Mountains	Northwest Dunn County
Blue Buttes*	Eastern McKenzie County

In addition to these areas the following areas are listed as belonging to the White River formation by Seager (26).

Area	Location
Young Man's Butte (mapped in this report)	Stark County east of Richardton
Antelope Buttes (mapped in this report)	Stark County east of Richardton
Lefor Buttes (mapped in this report as "Long" Butte)	Stark County west of Lefor
East and West Rainy Buttes	Northeast Slope County
H. T. and Bullion Buttes	Central Slope County
Flat Top Butte	East of Sentinel Butte

In 1948 Powers (24) described the following areas of White River exposures in North Dakota which had not been described before as White River deposits.

Colgrove Butte (and several small buttes just north of Colgrove Butte)	Northern Hettinger County
Bull Butte	Just west of Colgrove Butte in Hettinger County

Powers also mentioned several unnamed buttes in the Lefor district one of which was mapped as "School" Butte in Stark County south of Lefor. Two of Powers unnamed buttes east of School Butte were investigated, and one was mapped as "Straight" Butte.

* Not White River according to more recent work. See Geologic Map of North Dakota southwest of Missouri River, 1:500,000 U.S. Geological Survey Preliminary map, W. E. Benson, 1951.

Lithology

The White River formation in this area consists of three members--the basal sand, the middle clay, and the upper limestone and clay sequence.

The basal sand is thickest at Colgrove Butte where it is ten feet thick at sample station 2. (See map Figure 6) It is unconsolidated and has a drab yellow color due to intermixed clay. The clay is largely montmorillonite and is a decomposition product of volcanic ash which is found in this member. When the clay is washed out, the residue is seen to consist of very fine to coarse sand containing a few euhedral quartz crystals, crystals of cristobalite, hornblende, albite, quartz pebbles up to 1 centimeter in greatest diameter, chert pebbles and fossil wood fragments up to 2.5+ centimeters in greatest diameter with volcanic ash and fragments of tuff. Most of the sands and pebbles are sub-rounded, but they range from sub-angular to rounded.

Everywhere in the area clay lies above the basal sand. Usually gray or grayish-green in color and crumbly, this clay is normally non-calcareous to faintly calcareous. The clays next above are found to be calcareous, and the higher the clay lies in the section the higher its content of calcium carbonate.

Calcareous clays are found containing inclusions of balls of green, non-calcareous clays. The clays intercalated with the limestone beds at the top of the section exhibit the highest lime content, except for zones of limestone nodules sometimes found in the upper clays.

At the top of the formation the lithology of the limestone varies widely. Ordinarily the beds are one to two feet thick and consist of hard, dense, light-tan limestone with calcite crystals. There are usually two or three prominent ledges of this limestone interbedded with calcareous clays. Partial replacement by brown chert is common, some beds appearing to be almost 50 percent chert. Occasionally a limestone ledge four to five feet thick will be found. These thicker ledges normally consist of beds of varying lithology, from the dense limestone with secondary chert to very porous beds.

Some of the limestones are very high in clay, giving the rock a greenish cast. In other beds, usually the lowest beds in the section, green clay-ball inclusions in the limestone vary from 1 mm. to 10 cm. in diameter. When the clays weather out, the resultant pits cause a rough "vesicular" surface.

These limestone beds conform rather well to descriptions of White River limestones in South Dakota by Wanless (29) whose description follows: "At various levels throughout the Titantotherium and Lower Oreodon beds are thin sheets or lenses of white limestone. These are sometimes in the form of algal-ball levels made up of a series of flattened, oval-shaped balls which are often quite persistent. Elsewhere thin sheets of silicified limestones occur in which the original organic character has been almost destroyed by replacement by secondary silica."

"A third type of limestone forms a lens-shaped solid sheet a few acres in extent. This type develops a limestone as much as three feet thick and is quite rich in organic remains, especially the shells of cyprids."

Thickness

The White River formation in the mapped areas is remarkably constant in thickness. Measured sections vary from twenty-eight feet at Antelope Butte to thirty and one-half feet at Colgrove Butte. See sections, Figure 3 and 7.

Paleontology

Limestone Beds

Fossils of small gastropods are common in the limestone, but are so firmly held that none have been removed intact. Their casts are often observed in fresh fractures and at times even on weathered surfaces. Several good gastropod specimens were found in a semi-silicified, yellow-brown, argillaceous limestone on Colgrove Butte.

Selected specimens from the area have been identified as listed below by Dr. Teng-Chien Yen, Research Geologist of the Smithsonian Institution.

- Colgrove Butte -

Lymnea shumardi Meek and Hayden

Planorbis nebrascensis Evans and Shumard

Planorbis vetulus Meek and Hayden

Lacunorbis Sp.

- Long Butte -

Planorbis nebrascensis Evans and Shumard

Lymnea Sp.

- School Butte -

Lymnea Sp.

Planorbis Sp.

- Straight Butte -

Lymnea Sp.

Planorbis Sp.

Lymnea shurmardi, Planorbis nebrascensis and Planorbis vetulus are listed by Henderson (16) as being known only from the Oligocene of South Dakota.

Their presence in North Dakota provides faunal evidence of Oligocene age of the beds investigated in this report, which hitherto has been referred to the Oligocene on the basis of lithology and stratigraphic position.

Clay Beds

On the southwestern end of Long Butte in the uppermost clay bed, two fragments of fossil bone were discovered. These were the only indication of vertebrate fossils in the entire area mapped, in spite of dozens of excavations made at outcrops in each area.

Relation to Adjacent Formations

The basal White River apparently rests on lower Golden Valley beds at Young Man's, Antelope, and School Buttes. At Long Butte it rests on upper Golden Valley beds. At Colgrove and Bull Buttes basal White River rests on upper Tongue River beds. On the basis of the above it appears that the White River lies uncomformably upon a surface of low relief. The unconformity at the base of the White River formation was recognized by Clarke (9) who states that the White River beds were deposited on an uneven erosion surface and lie on different formations in various parts of the area he investigated. Inasmuch as it is not definitely known to be overlain by any formation in the State, its upper boundary relationships are not known.

Correlations

Correlations of the White River beds between the areas mapped in this report are good. However there appears to be no basis for direct correlations with other isolated areas of White River deposits in the state.

A recent report by Bump (7) indicates that this area can be correlated with the Chadron formation of South Dakota on lithologic evidence.

Three species of fresh water gastropods found in this area provide faunal evidence for correlation with the Oligocene of South Dakota.

Historical Interpretation

Schuchert and Dunbar (25) describe the Dakotas in Oligocene time as having a sub-tropical climate comparable to present day Florida. They mention Oligocene deposits as part of a series of Cenozoic formations spread east from the Rockies by rivers running nearly at grade. These descriptions are in accord with earlier writings by Wanless (29A) who states that the deposits were laid down in ponds on the flood plain and by sluggish streams which meandered across the plain in shallow channels. Hatcher (15) believed that the wind was responsible for most of the clay deposits and that the limestones were laid down in shallow ponds and lakes on higher table lands and on the flood plains of the rivers. Darton (12) considered the White River formation to be lacustrine.

The clay inclusions in both clays and limestones noted in this area were mentioned by Wanless (30) and were described by him as formed by fragments of the land surface being picked up by flood-waters and incorporated in the flood-deposited silts. It is certain that these inclusions were not transported very far since they are composed of soft, unindurated clay. The deposits in the areas of this report may reasonably be assumed to be due to stream-bed and flood-plain deposition, and deposition in small ponds and lakes on the flood-plain, some of which could have been ox-bow lakes. The type of deposit most commonly encountered in this locality seems to fit the latter particularly well, since currents of fair competency were required to carry the largest pebbles (1"+ greatest diameter) found in the basal sand. After formation of the ox-bow lake, clays and limestone might be expected to be deposited, forming beds such as are found in this area.

The volcanic ash and sand-bed which is found everywhere at the base of the White River in areas mapped for this report poses quite a problem as to its origin. The sand is composed chiefly of alpha quartz and chalcedony with minor amounts of cristobalite. Some of the cristobalite crystals are intimately intergrown with volcanic ash. Fragments of ash enclosing these crystals could well have been stream-borne to their present location.

Other components of this basal member, such as chert pebbles and bits of petrified wood, had previously been laid down in stream channels and were covered by the volcanic materials. Decomposition of the finer particles of ash resulted in the yellow clay which now masks all but the coarser components of this basal member.

Darton (12A) found volcanic ash in beds and as an admixture in clay and sand members in the White River group in South Dakota. He refers to ash in local lenses in the Chadron formation.

Douglass (13A) referred to the probably presence of volcanic ash in the middle White River beds at White Butte in North Dakota.

Leonard (20A) believed that the materials that make up the North Dakota Oligocene deposits were derived from the Rocky Mountains or the Black Hills, and that the clays were lacustrine while the coarse conglomerates were fluviatile.

PROBLEMS OF DEVELOPMENT

Problems of Quarrying

In the event of exploitation of these deposits, the process of quarrying the limestone would involve stripping of overburden first of all. This could be accomplished by bulldozers, or tractors and carryalls. Since all the limestone beds to be quarried lie on the butte tops, the problem would be to dispose of the stripped material, consisting chiefly of sod and top soil, so that it would not wash over adjacent crop or pasture land and invite damage claims. A solution presents itself in that the overburden could be dumped in a gulch on the flanks of the buttes and washing could be largely prevented by the construction of a low earth fill dam with a proper overflow device.

As the work progressed and the lowest beds of limestone were removed in one location, stripping from adjacent portions could be deposited on the worked out section and washing could be cut to a minimum by constructing a low dike around the edge of the piles of stripping.

The limestone beds up to about one foot thick are commonly found to be jointed and fractured and would present no great difficulty in quarrying. The thicker beds up to two feet thick could be broken up by dropping a heavy weight on them. A small crane with a boom and a cable to lift a heavy, malleable iron ball could be used for this purpose. Explosives would undoubtedly be required to break the beds that are more than two feet thick.

Dr. Alex Burr, director of the North Dakota Research Foundation, advises in a personal communication that the basic plan provides for upgrading the material for cement manufacture, and the lower limit acceptable for upgrading has been set at 50 percent calcium carbonate content. On this basis some of the clays between the limestone beds are classed as usable material. Since the clays are soft and unindurated they could easily be picked up with a power shovel. Some beds are closer in appearance to limestone than to clays, but are poorly indurated and well jointed. A rooter could be used to loosen up the material so that a power shovel could pick it up.

Availability of Fuel and Water

Fuel

Lignite beds under eight to fifteen feet of overburden were formerly mined from pits on the Dobitz farm in Sec. 7, T. 136N., R. 94W., just south of School Butte. The beds are reported to be about eight feet thick. In past years local residents commonly pooled labor and equipment and dug lignite from pits such as the ones on the Dobitz farm. George Lefor of Lefor, North Dakota, has drilled a number of wells for farmers in the area, and he reports lignite beds penetrated in several wells at widely separated locations. All the limestone deposits mapped are within the area of lignite beds eight feet or more in thickness as shown on a map (23) prepared by the North Dakota Geological Survey.

Water

The lignite pits on the Dobitz farm are full of water and have not been known to dry up in the past several years. Pumping tests would have to be made in order to determine how much water can be obtained from wells drawing water from this lignite bed or other ground water horizons in the area. A system of several wells might be required to provide an adequate supply of water.

OVERBURDEN, AND QUANTITIES OF LIMESTONE AVAILABLE

General Statement

Quantities of overburden and limestone have been estimated on the basis of an average of all the outcrops and test holes. Beds assaying 50 percent calcium carbonate or higher are classed as limestone. Beds assaying lower than 50 percent calcium carbonate are classed as overburden. The total stripping is computed and compared with the total amount of limestone available. Except for a thin layer of top soil, overburden material to be removed by stripping consists of clay and limestones high in chert.

- Quantities of Limestone and Overburden in Mapped Areas -

Area	Total Stripping of Overburden Cubic Yards	Total Available Limestone Containing 50% or Higher $CaCO_3$ Cubic Yards	Tons (12 cu.ft.per ton)
Antelope Butte[1]	7,000	10,500	23,625
Young Man's Butte[1]	1,440	1,680	3,770
School Butte[2,4]	1,387,438	1,064,778	2,395,750
Straight Butte[3]	613,054	1,226,108	2,758,743
Long Butte[4]	1,677,832	2,516,748	5,662,683
Colgrove Butte[4]	3,952,585	3,952,585	8,893,336
Bull Butte[1,3]	315,000	419,000	942,083

1 Small areas, small quantities of available limestone
2 Test drilling shows thin limestones
3 No test drilling
4 High overburden to limestone ratio

GEOLOGIC CONCLUSIONS

1. Antelope Butte and Young Man's Butte are too small to be of value as sources of limestone for cement manufacture.
2. The discontinuity of the limestone beds has been demonstrated in the sections prepared for each butte mapped. (See illustrations).
3. In spite of the discontinuity of the limestone beds, a sufficient number of samples has been obtained from Long, School, Colgrove, Straight, and Bull Buttes to give a reasonably accurate average for chemical analysis and available yardages.
4. Although no individual beds can be traced from one butte to another and few can be traced continuously on any one butte, the limestone-clay sequence represents the same member everywhere in the mapped area.
5. The presence of chert in the limestone at several outcrops and in one test hole on Colgrove Butte need only be mentioned here since it will receive consideration in the economic section of this report.

GENERAL DISCUSSION OF MAPPED AREAS

The following general descriptions of the buttes have been included in order to assist the reader in making use of the illustrations accompanying the text of this report.

Antelope Butte, Figures 1 and 3; and Young Man's Butte, Figures 2 and 3 are both considered too small to be worthy of further consideration as sources of limestone for cement manufacture.

Bull Butte is readily accessible from the north, east, and west sides by fairly well-graded roads which are passable in dry weather. The limestone deposit at Bull Butte, Figure 4, is small but of comparatively good quality. The first samples taken at Bull Butte showed the lower beds to be unusually high in calcium carbonate. Since this was out of character with similar beds elsewhere in the area, Bull Butte was re-sampled. The results of calcium carbonate determinations of the second or duplicate set of samples are shown in Figure 5. The results of calcium carbonate determinations for the original samples number 30, 31, and 32 are to be disregarded. Two additional samples numbered 31A and 32A were taken to increase the accuracy of estimates of limestone and overburden yardages.

Colgrove Butte is located less than one half a mile northeast of Bull Butte, and is reached by the same road-net. A road along the north line of section 17 follows the most gradual slope to the top of Colgrove Butte as shown in Figure 6. Colgrove Butte with a top area of 0.9 of one square mile is the largest of all the buttes mapped. However, as shown in Figure 7A there is a relatively large amount of overburden material containing less than the required 50 percent of calcium carbonate, and there is also a considerable amount of chert which is undesirable. The discontinuity of high calcium carbonate beds on Colgrove Butte is indicated in Figure 7B and 7C which also show the presence of chert and the large amount of overburden to be removed in comparison to the amount of limestone available. Colgrove Butte is not considered to be a very satisfactory source of limestone since the presence of chert would entail excessive handling and grinding costs. The large amount of overburden in comparison to limestone would result in excessive cost in stripping of overburden. Very close chemical control would be required to avoid putting low grade material through the manufacturing process, and, on the other hand, to avoid stripping usable material as overburden.

Long Butte is distinguished by a long narrow ridge trending northwest from the main body of the butte. Long Butte is accessible by a well-graded gravel road and by several unsurfaced roads from the vicinity of the village of Lefor, two miles to the east. Test drilling on the main body of Long Butte as shown in Figure 9B, revealed a seven foot thickness of usable material lying under three to five feet of overburden. The amount of overburden to be removed in relation to available limestone is not so unfavorable as on Colgrove Butte although it is still high as indicated in Figures 9 and 9A. Long Butte with a top area of 0.4 of one square mile is considered a fair source of limestone for cement manufacture in spite of high yardages of overburden.

School Butte is located two miles southwest of Long Butte and is accessible by a gravel road from Lefor to the north and by unsurfaced roads from the vicinity of Colgrove and Bull Butte to the east. School Butte, Figure 10, has a top area of 0.4 of one square mile, as shown in Figure 11. The limestones are generally thin and low in calcium carbonate and yardages of overburden to be removed exceed yardages of limestone available as shown in the table on page 16. Therefore, School Butte is not considered a good source of limestone for cement manufacture.

Straight Butte can be reached by the same road-nets that provide access to School Butte, two miles to the west. Straight Butte, Figure 14, also has a top area of 0.3 of one square mile. No test holes were drilled on this butte and samples are not encouraging due to the fact that the beds of high calcium carbonate content are generally thin as shown in sections, Figure 13, 13A, and 13B. Although overburden to be removed at Straight Butte amounts to only one half the amount of limestone available as shown in the table on page 16. Straight Butte is not recommended as a source of limestone for cement manufacture because the thin beds would make it difficult to keep overburden and usable material separate by machine methods.

APPENDIX A

Location of Areas

Sample numbers and locations are given for those samples not located by number on accompanying maps and for the samples taken from outside the mapped areas.

<u>Stark County</u>

Young Man's Butte		T.139N.,R.91W., Sections 11 and 12
Antelope Butte		T.139N.,R.91W., Sections 16 and 21
Long Butte		T.137N.,R.94W., Sections 19, 29, and 30 and T.137N.,R.95W., Sections 12, 13, 24, and 25
Long Butte clays	Sample 51	T.137N.,R.94W., Section 18
		T.137N.,R.95W., Section 13
	Sample 54	T.137N.,R.95W., Section 12
Little Bad Lands	Sample 59	T.138N.,R.98W., Sections 23 and 24
Dickinson Area	Sample 56	T.139N.,R.96W., Section 8
	Sample 55	T.139N.,R.95W., Section 5

<u>Hettinger</u>

School Butte		T.136N.,R.94W., Sections 5,6,7, and 8
Colgrove Butte		T.136N.,R.93W., Sections 8,9,16, and 17
Clay	Sample 50	NW/4 Section 17, T.136N.,R.93W.
Bull Butte		T.136N.,R.93W., Section 18
Straight Butte (Stark and Hettinger)		T.136N.,R.94W., Sections 3 and 4
		T.137N.,R.93W., Section 31
		T.137N.,R.94W., Section 36

<u>Dunn County</u>

Killdeer Mountain samples		
North Mountain	Sample 58	T.146N.,R.96W., Section 2
South Mountain	Sample 57	T.146N.,R.96W., Section 22

<u>Morton County</u>

Clay Pit used by Hebron Brick Plant	Samples 52 and 53	T.140N.,R.90W., Section 11

<u>Pembina County</u>

Test Holes, Cretaceous shale T.161N., R.56W., Sections 23,24,34,35,& 36

Cavalier County

Mayo Brick Plant	Sample 65	T.163N.,R.57W., Section 34
Road Cut	Sample 66	T.163N.,R.57W., Section 18

APPENDIX B

General Discussion of Samples Obtained from Outside the Mapped Areas

Killdeer Mountains

Two samples were taken in the Killdeer Mountains (See Location Map No. 1). The Killdeer Mountains had previously been ruled out by Burr (8A) as a possible source for cement materials, and the samples taken substantiated the earlier opinion.

Long Butte Clays

Two samples were obtained from the upper Golden Valley clay exposures of Eocene age near Long Butte. Sample 51 was taken from the same location as the geologic section described in this report on page 7 .

Little Bad Lands, Dickinson Area, and Hebron Clay Pit

Samples of clays (see Location Map No. 1) were obtained from the above areas to determine whether such clays might be used as a source of cement materials in the event that clays in the mapped areas should prove unsuitable.

The clays from the Little Bad Lands district are from the Oligocene White River formation, while those from the Dickinson area and from the Hebron clay pit are found in the Golden Valley formation of the Eocene.

Old Mayo Brick Plant and Walhalla Area Cement Rock Samples

Samples were taken at the above areas (see Location Map No. 2) to supplement a number of samples of cement rock from the Niobrara formation of Cretaceous age taken during an earlier investigation (see text page 4).

APPENDIX C

Logs of Test Holes

Test holes were drilled on Colgrove, Long, and School buttes and can be located by samples number either on the topographic maps or on the outline maps of the limestone deposits. All beds penetrated by the test holes belong to the White River formation.

Colgrove Butte

44	Top soil	0"	- 1' 9"
	Limestone	1' 9"	- 5' 1"
	Clay, green	5' 1"	- 9' 0"
	Limestone	9' 0"	- 10' 0"
	Clay	10' 0"	- 16' 0"
	Limestone	16' 0"	- 18'10"
	Clay, green	18'10"	- 25' 0"

45	Top soil	0 - 1' 0"
	Limestone	1' 0" - 5' 0"
	Clay, calcareous	5' 0" - 9' 4"
	Limestone	9' 4" - 11' 6"
	Clay, Calcareous	11' 6" - 13'10"
	Limestone	13'10" - 15' 6"
	Clay	15' 6" - 26' 0"
	Clay, sandy	26' 0" - 27' 0"

46	Top soil	0 - 1' 4"
	Limestone	1' 4" - 3' 8"
	Clay	3' 8" - 11' 0"
	Limestone	11' 0" - 13' 4"
	Clay	13' 4" - 14'10"
	Limestone	14'10" - 17' 0"
	Clay	17' 0" - 19' 2"
	Limestone	19' 2" - 20' 0"
	Clay	20' 0" - 25' 0"

47	Top soil	0 - 1' 0"
	Limestone	1' 0" - 3' 6"
	Clay	3' 6" - 6' 7"
	Limestone	6' 7" - 7' 4"
	Clay	7' 4" - 11' 2"
	Limestone	11' 2" - 14' 0"
	Clay	14' 0" - 25' 0"

48	Top soil	0 - 10"
	Limestone	10" - 4' 0"
	Clay	4' 0" - 5' 0"
	Limestone	5' 0" - 7' 0"
	Clay	7' 0" - 8' 0"
	Limestone	8' 0" - 9' 0"
	Clay	9' 0" - 9' 6"
	Limestone, with chert	9' 6" - 11' 4"
	Clay	11' 4" - 25'

49	Top soil	0 - 2' 0"
	Limestone-clay	2' 0" - 2' 6"
	Clay, calcareous	2' 6" - 6' 0"
	Limestone, soft	6' 0" - 7' 0"
	Limestone, hard	7' 0" - 8' 6"
	Limestone, soft	8' 6" - 10' 0"
	Limestone, hard	10' 0" - 10'10"
	Limestone, soft	10'10" - 14' 0"
	Clay	14' 0" - 25' 0"

School Butte

60	Top soil, earthy clay	0 - 4' 8"
	Limestone	4' 8" - 6' 0"
	Clay	6' 0" - 7' 2"
	Limestone	7' 2" - 7' 9"
	Clay	7' 9" - 11' 0"
	Limestone	11' 0" - 11' 9"
	Clay, thin limestone	11' 9" - 25' 0"

61	Top soil	0 - 1' 0"
	Clay, earthy	1' 0" - 2' 0"
	Limestone	2' 0" - 3' 8"
	Clay, thin limestone	3' 8" - 9' 8"
	Limestone	9' 8" - 11' 0"
	Clay	11' 0" - 14'10"
	Limestone	14'10" - 15' 7"
	Clay	15' 7" - 28' 0"
	Clay, sandy	28' 0" - 29' 0"

Long Butte

62	Top soil	0 - 1' 6"
	Clay	1' 6" - 2' 6"
	Limestone	2' 6" - 3' 8"
	Clay	3' 8" - 4' 3"
	Limestone	4' 3" - 5'10"
	Clay	5'10" - 7' 0"
	Limestone	7' 0" - 8' 0"
	Clay, thin limestone	8' 0" - 19' 0"
	Limestone	19' 0" - 20' 0"
	Clay	20' 0" - 25' 0"

63	Top soil	0 - 1' 6"
	Clay, calcareous	1' 6" - 3' 9"
	Limestone	3' 9" - 6' 0"
	Clay	6' 0" - 9' 6"
	Limestone	9' 6" - 12' 0"
	Clay	12' 0" - 14' 2"
	Limestone	14' 2" - 16' 0"
	Clay	16' 0" - 17' 6"
	Limestone	17' 6" - 18' 0"
	Clay	18' 0" - 25' 0"
	Clay, sandy	25' 0" - 26' 0"

64	Top soil	0 - 1' 6"
	Clay, calcareous	1' 6" - 3' 8"
	Limestone	3' 8" - 4' 9"
	Clay	4' 9" - 7' 0"
	Limestone	7' 0" - 9' 0"
	Clay	9' 0" - 14' 0"
	Limestone	14' 0" - 15' 0"
	Clay	15' 0" - 18' 6"
	Limestone	18' 6" - 21' 0"
	Clay	21' 0" - 25' 0"

APPENDIX D

Detailed Sections

The sections in the area of this report are given the same number as the sample location at which they were measured. Thus the sections can be located either on the topographic map or on the outline map of the limestone deposit of each butte.

Antelope Butte

<u>36</u> White River Formation

3	Limestone, gray, thick to thin bedded, intercalated with thin clays and thin brittle flaky limestone layers	1'8"
2	Limestone, tan-gray, with calcite crystals and minor chert, thick to thin bedded	1'6"
1	Limestone, white, thin bedded, thin clays, minor chert	1'2"
	Clay, gray-green, faintly calcareous	

(Antelope Butte, west end, not sampled)

White River Formation

6	Limestone, tan-gray with calcite crystals, thick to thin bedded	1'
5	Covered, slumped blocks of limestone	10'
4	Clay, gray, calcareous	11'
3	Quartz sand, fine to coarse, with clay and volcanic ash	6'

Golden Valley Formation

2	Clay, purple-yellow-brown with fossil wood, iron oxide concretions, carbonaceous matter of very fine grained sands	30'
1	Sandstone, brown, fine grained, micaceous, cross-bedded calcareous	6'

Bull Butte

<u>30</u> White River Formation

2	Limestone, tan, dense	2'6"
1	Limestone, gray-green, soft, blocky, with green clay inclusions	16'

<u>31</u> White River Formation

2	Limestone, tan, dense, with calcite crystals	1'2"
1	Limestone, gray, soft, with clay inclusions, two thin zones of limestone nodules	15'

32 White River Formation

6	Limestone, tan, dense, with calcite crystals, minor chert and clay	2'6"
5	Limestone, gray, high in clay	12'
4	Clay, gray-green, calcareous	3'
3	Quartz sand, fine to coarse with clay and volcanic ash	8'6"

Tongue River Formation

2	Clay, gray, yellow-green, non calcareous	5'6"
1	Sand, light brown, very fine grained silty, with iron oxide concretions and large irregular sandstone concretions	22' +

31A White River Formation

3	Limestone, gray, hard 6" of gray-green calcareous clay at base	2'
2	Limestone, gray, hard, thick bedded	3'
1	Clay-limestone, soft, blocky	1'6"+

32A White River Formation

3	Clay, gray, calcareous	4'6"
2	Clay-limestone, soft, blocky gray-green	5'0"
1	Limestone, gray, hard	2'4"

Colgrove Butte

1 White River Formation

5	Limestone, tan-gray, dense, with calcite crystals and stringers	1'4"
4	Limestone, much brown chert	8"
3	Limestone, tan-gray, dense at top, porous below	1'
2	Limestone, brown chert	4"
1	Limestone, minor chert	1'
	Clay, gray-green, non calcareous (At Base)	

2 White River Formation

4	Limestone, tan-gray, dense, with minor chert	9"
3	Clay, calcareous, gray-white, crumbly	1'6"
2	Limestone, light gray, dense	1'4"
1	Limestone, gray, soft, high in clay	12'

3 White River Formation

7	Clay, gray, crumbly	5'
6	Quartz sand, tan, uncemented, fine to coarse with clay and volcanic ash	10'

Tongue River Formation

5	Clay, gray-green non-calcareous	3'

4	Sand, gray, very fine grained	4'
3	Sand, gray-maroon very fine grained, high in clay	6'
2	Sand, gray, very fine grained high in clay	7'6"
1	Sand, tan, very fine grained high in clay	12'+

Sections 2 and 3 are from the same location, separation only for purposes of sampling. Bed 7 in section No. 3 lies immediately below bed 1 in section No. 2.

4 White River Formation

4	Limestone, gray, with calcite crystals, weathered mixed with sod	10"
3	Clay, gray-green at base to gray white at top, calcareous	8'
2	Limestone, tan-gray, with calcite crystals	1'
1	Limestone, gray, soft, high in clay	11'

5 White River Formation

4	Limestone, gray, weathered	4"-6"
3	Limestone, gray, soft, crumbly	8"
2	Limestone, tan-gray with calcite crystals, much brown chert, fossiliferous	2'9"
1	Limestone, gray, soft, high in clay	11'3"

6 White River Formation

4	Limestone, tan-gray, weathered	10"
3	Limestone, gray, crumbly	1'
2	Limestone, tan-gray with calcite crystals, fossiliferous, near middle of bed an 8" porous layer lies above a 4" cherty layer	3'
1	Clay, gray-green calcareous	12'

7 White River Formation

2	Limestone, tan-gray, with calcite crystals, much chert	2'
1	Clay, gray-green, non-calcareous, earthy matrix	4'
	Clay, green, sandy, faintly calcareous (At Base)	

8 White River Formation

3	Limestone, tan-gray, dense, with calcite crystals	1'4"
2	Clay, gray-green, calcareous at top green, brittle, non-calcareous near base	5'
1	Limestone, gray-white with non-calcareous green clay inclusions from less than 1 mm. to more than 1 cm., in upper portion clay balls are as large as 10 cm. in diameter	

9 White River Formation

6	Limestone, gray, weathered, mixed with sod	1'
5	Clay, calcareous with zones of limestone nodules	17'
4	Clay, yellow-brown to gray-green, non calcareous	5'
3	Quartz sand, fine to coarse, conglomeratic at base with clay and volcanic ash	9'

Tongue River Formation

2	Clay, gray-green at top with iron oxide stain colors change downward to yellow-brown-purple	6' 3"
1	Sand, gray-green, micaceous	2' 2"
	Sand, yellow-green, very fine grained (At base)	

10 White River Formation

2	Clay, calcareous, gray-green, with green clay inclusions and a few thin nodular limestone layers	8'
1	Limestone, cherty, argillaceous, fossiliferous	4' +

11 White River Formation

2	Clay, gray-green, calcareous, soft, blocky	16' 6"
1	Limestone, gray-white with calcite crystals	1' 2"

34 White River Formation

2	Limestone, gray, dense, much brown chert in upper 18" of bed	2'
1	Clay, gray, calcareous, crumbly	6"
	Clay, gray-green, non-calcareous (At Base)	

35 White River Formation

2	Clay, gray, calcareous with three thin limestone layers	8'
1	Limestone, tan-gray, with calcite crystals	10"
	Clay, faintly calcareous, brown (At Base)	

Long Butte

12 White River Formation

7	Clay, calcareous and limestone float	2' 4"
6	Clay, gray-green calcareous	4'
5	Limestone, tan-gray, dense with calcite crystals	1'
4	Clay, gray-green, non calcareous at base to calcareous at top	5' 3"
3	Limestone, gray with small green clay inclusions 1-5 mm. diameter	1' 5"
2	Clay, gray, calcareous	9' 6"
1	Quartz sand, fine to coarse with clay and volcanic ash	5' 6"

13 White River Formation

5	Limestone, tan-gray weathered	6"
4	Clay, gray, calcareous	6'
3	Limestone, tan-gray with calcite crystals	1'10"
2	Clay, gray, calcareous	4' 2"
1	Clay, gray-green, calcareous	11'
	Quartz sand, fine to coarse with clay and volcanic ash (At base)	

14	White River Formation		
	5	Limestone, gray, weathered, about 50% chert	1' 2"
	4	Clay, gray, calcareous with limestone nodules	8'
	3	Limestone, gray, with calcite crystals and stringers	6"
	2	Limestone, gray, soft, high in clay	2'
	1	Limestone, tan-gray, high in clay at base, thick to thin bedded porous near middle of bed, fossiliferous near top with 2" cherty layer at top	5' 3"
15	White River Formation		
	2	Limestone, tan-gray with calcite crystals and stringers	3'
	1	Clay, gray, calcareous with limestone nodules	7' 6"
16	White River formation		
	5	Limestone, gray, weathered	6"
	4	Clay, gray-white, calcareous	3'
	3	Limestone, gray, with calcite crystals, small green clay inclusions	1'
	2	Clay, gray green in calcareous clay matrix	5' 6"
	1	Limestone, gray	1' 6"
17	White River Formation		
	3	Limestone, gray, with calcite crystals	1' 6"
	2	Clay, gray-white, calcareous	1' 9"
	1	Limestone, tan-gray, with calcite crystals	1'
33	White River Formation		
	3	Clay, gray calcareous	1'
	2	Limestone, gray, soft, and blocky	3'
	1	Limestone, gray-green, high in clay	1'10"
		Clay, green, non-calcareous (At base)	
34A	White River Formation		
	5	Limestone, tan-gray with minor chert, weathered	1'
	4	Clay, gray, calcareous	8' 8"
	3	Limestone, tan-gray, with calcite crystals, thick to thin bedded	3'
	2	Clay, gray-green, calcareous	4"
	1	Limestone, gray, with calcite crystals	3' 6"
38	White River Formation		
	3	Limestone, tan-gray, with calcite crystals	1' 4"
	2	Clay, gray, calcareous	6'
	1	Limestone, tan-gray, fossiliferous, upper 10" cherty	4'
39	White River Formation		
	4	Limestone, tan-gray, with calcite crystals and stringers, and green clay inclusions from 1 mm. to 2.5 cm. in diameter	1'

3	Clay, gray, calcareous, green clay inclusions	4' 8"
2	Clay, gray-green, mixed with gray calcareous clay	6'
1	Clay, tan gray, non-calcareous	2' +

40 White River Formation

5	Limestone, gray, with calcite crystals	1' 2"
4	Clay, white-gray, calcareous	2'
3	Limestone, gray, with calcite crystals	2' 4"
2	Limestone, gray, soft, blocky, high in clay	5'
1	Clay, gray-green, calcareous	---

41 White River Formation

2	Clay, white, calcareous with limestone nodules	1' 4"
1	Limestone, gray, soft, blocky	6'+

42 White River Formation

3	Limestone, gray, with calcite crystals	1' 6"
2	Clay, gray, calcareous with limestone nodules	3' 6"
1	Clay, gray-green, calcareous	4'+

School Butte

18 White River Formation

3	Clay, gray, calcareous, limestone float	2' 6"
2	Limestone, tan-gray, with calcite crystals	10"
1	Limestone, gray-white, with clay inclusions	1' 8"

19 White River Formation

5	Limestone, gray	11"
4	Clay, calcareous, with limestone nodules	9"
3	Limestone, gray	1' 2"
2	Clay, gray, calcareous, with limestone nodules	2' 8"
1	Limestone, tan-gray, with calcite crystals	8"

20 White River Formation

4	Clay, gray, calcareous, with zones of limestone nodules	5' 6"
3	Limestone, gray, with clay inclusions, and calcite crystals	1'10"
2	Clay, gray-green, calcareous	9"
1	Limestone, gray, with calcite crystals and small green clay inclusions about 1 mm. in diameter	4' 2"

21 White River Formation

4	Limestone, gray, with calcite crystals weathered	6"
3	Clay, gray, calcareous	2' 8"
2	Limestone soft at base, high in clay, upper 1' harder, tan-gray with calcite crystals	2' 0"
1	Clay, gray-green, calcareous	2'

22 White River Formation

5	Limestone, gray, with calcite crystals, and clay inclusions	1'
4	Clay, gray-green, calcareous	4' 2"
3	Limestone, gray, with calcite crystals	1' 3"
2	Clay, gray, calcareous, with limestone nodules	9"
1	Limestone, gray, with calcite crystals	1' 1"

36A White River Formation

4	Limestone, tan-gray with calcite stringers and green clay inclusions from 1 mm. to 1 cm. in diameter	6"
3	Clay, gray, calcareous, green clay at top	2' 8"
2	Limestone, gray with calcite stringers and green clay inclusions at top, middle portion soft, high in clay, bottom of bed harder with calcite crystals	3'
1	Clay, gray-brown, calcareous, with green clay inclusions	5'+

37 White River Formation

2	Clay, gray, calcareous, with limestone nodules	4'
1	Clay, gray-green, non calcareous	2' 6"

Straight Butte

26 White River Formation

6	Limestone, weathered, mixed with top soil	6"
5	Clay, gray, calcareous, crumbly	2' 9"
4	Limestone, tan, dense, with minor chert	1' 6"
3	Limestone, soft, blocky	1' 6"
2	Limestone, tan-gray	1'
1	Clay, gray, calcareous	5'

27 White River Formation

4	Limestone, weathered, mixed with top soil, fossiliferous	6"
3	Clay, gray-green, calcareous	3' 4"
2	Limestone, tan, dense	10"
1	Clay, gray, calcareous, thin limestone layers	11"

28 White River Formation

4	Limestone, gray	7"
3	Limestone, high in clay, soft	1' 9"
2	Limestone, gray	10"
1	Limestone, high in clay, soft, blocky	3' 4"

29 White River Formation

3	Clay, gray-green, calcareous	3'
2	Limestone, green clay inclusions, soft, blocky	3'
1	Limestone, much chert and clay inclusions (1-100 mm. diameter)	6"

67 White River Formation

4	Clay, calcareous with limestone nodules	2' 0"
3	Limestone, soft, blocky, high in clay	4' 6"
2	Limestone, hard, with clay inclusions	1' 0"
1	Clay, calcareous	---

68 White River Formation

2	Limestone, hard, gray, dense	1' 6"
1	Clay, green, crumbly, calcareous at top	10'+

69 White River Formation

2	Limestone, gray hard	1' 4"
1	Clay, gray, calcareous	10'+

70 White River Formation

2	Limestone, gray	0' 6"
1	Clay, gray, calcareous	6'+

71 White River Formation

4	Clay, gray, calcareous with limestone fragments at top	3' 0"
3	Limestone	0' 6"
2	Clay, calcareous	5' 6"
1	Limestone, gray	0' 9"

72 White River Formation

2	Limestone, gray, dense	1' 6"
1	Clay, gray, calcareous	12'+

Young Man's Butte

43 White River Formation

5	Limestone, thin bedded, intercalated with thin clays	2'
4	Limestone, gray, hard at top and at base, softer in middle of bed	6' 3"
3	Clay, gray, calcareous	8' 10"
2	Limestone, gray, with calcite crystals	3' 10"
1	Clay, gray, calcareous	3'

APPENDIX E

Comments on the Geologic Report

by Oliver Bowles

A geologic report on the limestones of Stark and Hettinger Counties, was prepared by Miller Hansen, Geologist, under direction of Dr. Wilson M. Laird, State Geologist of North Dakota. The limestones of the area occur only as flat-lying beds capping scattered buttes that rise 100 feet or more above the general level. The geology of the limestone beds is described in relation to overlying and underlying formations, and their lithologic character and general composition are discussed. Previous work done by other geologists is cited in many references, and such work is fully considered as supplementary to the writer's field work in determining the geologic history of the area and the origin of the limestones. The locations of the deposits by township, range, and section are given. Each limestone deposit is mapped, and a contour map is furnished for each butte. For most of them the contour interval is twenty feet.

An important phase of the work was the selection of representative samples from each deposit. The sampling was done under the supervision of the geologist who prepared this report. The locations of both outcrop and drill-hole samples are marked on the maps. The samples were analyzed by the North Dakota Research Foundation under the supervision of Dr. Alex C. Burr, Director of Research. As an important phase of the problem is to determine the suitability of the limestones for cement manufacture, the analyses covered the three critical constituents, lime, alumina plus iron, and silica.

Assay cross sections for each sample are superimposed on the maps, accompanied by a vertical scale showing elevations at one-foot intervals above sea level. The chemical analyses of the fractions of each sample are shown on the map. This graphic presentation permits ready observation of the composition of each fraction, as easy determination of the average composition of each sample, and the vertical range of the material sampled.

Logs of the test holes sunk on Colgrove, School, and Long Buttes show the succession of limestone, clay, and calcareous clay beds, and the thickness of each. Also detailed sections are given for each outcrop sample location. The thoroughness of the sampling, the reliability of the assay work, and the care with which the analytical data are related to the formations are worthy of comment.

The excellence of the maps is an outstanding feature. The wide scope of the report, the adequacy of detail both on maps and in the text, and the completeness and accuracy of coverage are of special merit as aids in evaluating the extent and quality of the limestone.

APPENDIX F

Natural Cement Possibilities

Argillaceous Limestone of Pembina and Cavalier Counties

By Oliver Bowles

Extensive deposits of clay-bearing limestones occur in northern North Dakota. They are so low in lime that they probably could not be beneficiated enough to furnish a satisfactory raw material for Portland cement manufacture. However, in certain areas, notably in bluffs along the Pembina River, they have a composition satisfactory for making natural cement.

Natural cement is the product formed by calcining a natural clay-bearing limestone without preliminary mixing or grinding. It is calcined at a much lower temperature than that required for Portland cement. The calcined product is ground to a fine powder.

The range of composition of the raw material is much more flexible for natural than for Portland cement. The lime (CaO) content may range from twenty to thirty-eight percent, and the silica-alumina-iron proportion from sixteen to thirty-five percent. Segments of the deposits in North Dakota that fall within the range of composition given above are extensive enough to supply a cement plant of moderate size for many years. A small natural cement plant operated at Concrete, Pembina County, from 1902 to 1909, and the product made was said to be of high quality. The lime content of the rock used averaged about thirty-six percent, and the alumina-iron-silica about twenty-three percent. The presence of large supplies of rock falling within the range of composition mentioned above has been confirmed by later analyses.

APPENDIX G

Bibliography

1. Alden, W. C. Physiographic Development of the Great Plains, Bull. Geol. Soc. of Amer. Vol. 35, pp. 389-390, p. 393 and Plate II, 1924.

2. Bavendick, F. J. Climate and Weather in North Dakota, p. 50. U. S. Weather Bureau, Bismarck, North Dakota, 1946, published in cooperation with the North Dakota State Water Conservation Commission.

3. Benson, W. E. Golden Valley Formation of North Dakota, (abstract) Bull. Geol. Soc. of Amer. Vol. 60, Pt. 2, pp. 1873-1874, 1949.

4. Benson, W. E. Unpublished manuscript on the Golden Valley Formation of North Dakota, 1951, in files of North Dakota Geological Survey.

5. Benson, W. E. and Laird, W. M. Unpublished manuscript on the Golden Valley Formation of North Dakota, 1947.

6. Brown, R. W. Correlation of Sentinel Butte Shale in Western North Dakota, Bull. Amer. Assoc. of Pet. Geol. Vol. 32, No. 7, pp. 1265-74, 1948.

7. Bump, James D. The White River Badlands of South Dakota: Guide Book, Fifth Field Conference of the Society of Vertebrate Paleontology in Western South Dakota, p. 34, pp. 38-39, 1951. Sponsored by the Museum of Geology, South Dakota School of Mines and Technology.

8. Burr, Alex. C. et al Is a Portland Cement Plant Technically and Economically Practical in North Dakota? Part II, Are Raw Materials Available in Sufficient Quantity and of Satisfactory Quality to Justify a Plant: pp. 10-17, 1949. Published by the North Dakota Research Foundation, Bismarck, North Dakota.

8A. p. 14

9. Clarke, Fremont F. Southwestern North Dakota Clay Deposits, Stark, Slope, and Billings Counties, North Dakota, U. S. Bureau of Mines Report of Investigation No. 4219, p. 7, 1948.

10. Collier, A. J. and Thom, W. T. The Flaxville Gravel and its Relation to other Terrace Gravels of the Northern Great Plains, U. S. Geol. Survey Prof. Paper 108J, p. 181, 1917.

11. Cope, E. D. White River beds near Sully Springs, Dakota, Proc. Amer. Philos. Soc., Vol. 21, pp. 216-217, 1884.

12. Darton, N. H. Preliminary Description of the Geology and Water Resources of the Southern Half of the Black Hills and adjoining Regions in South Dakota and Wyoming, U. S. Geol. Survey, 21st Annual Report, Part IV, p. 558, 1899-1900.

12A. P. 544

13. Douglass, Earl Reference from Leonard, A. G. Geology of Southwestern North Dakota, North Dakota Geological Survey, 5th Biennial Report, p. 67, 1908.

13A. p. 69

14. Hall, Thomas Laws of North Dakota, Chapter 34, p. 38, 1951. Published under Legislative Authority by the Secretary of State, Bismarck, North Dakota.

15. Hatcher, J. B. Origin of Oligocene and Miocene Deposits of the Great Plains, Amer. Philos. Soc. Pro. Vol. 11, No. 169, p. 127, 1902.

16. Henderson, Junius,Fossil Non-Marine Mollusca of North America, Geol. Soc. of Amer. Special Papers No. 3, pp. 240, 248, and 253, 1935.

17. Laird, W. M. et al Additional Well Logs for North Dakota, North Dakota Geol. Survey, Report of Investigations No. 7, pp. 59-60, 1952.

18. Leonard, A. G. Geology of Southwestern North Dakota, North Dakota Geological Survey, Fifth Biennial Report, pp. 51-52, 1908.

18A. pp. 44-64

18B. p. 65

18C. p. 67

18D. p. 68

19. Leonard, A. G. The White River Formation in North Dakota, University of North Dakota, Quart. Jour. Vol. 12, No. 3, April, 1922.

20. Leonard, A. G. Geological History of North Dakota, North Dakota Geological Survey, 5th Biennial Report, pp. 235-238, 1908.

20A. pp. 238-239

21. Meek, F. B. and Hayden, F. V. Descriptions of New Species and Genera of Fossils Collected by Dr. F. V. Hayden in Nebraska Territory, Phila. Acad. Nat. Sci. Proc., Vol. 9, pp. 119, 133, 1857.

22. Meek, F. B. and Hayden, F. V. Reference from Wilmarth, M. G., Lexicon of Geologic Names of the United States, U. S. Geol. Survey Bull. 896, Part II, p. 2835, 1938.

23. North Dakota Geological Survey, Map, Known locations of Lignite Beds Eight Feet or More in Thickness, in files of N. D. Geol. Survey.

24. Powers, W. E. Unpublished report in the files of the North Dakota Geological Survey, 1945.

25. Schuchert, C. and Dunbar, C. O. Textbook of Geology, Part II, Fourth Edition, pp. 397-399, 416, 1946.

26. Seager, O. A. et al Discussion, Stratigraphy of North Dakota, Bull. of the Amer. Assoc. of Pet. Geol., Vol. 26, No. 8, pp. 1415-16, 1942.

27. Simpson, H. E. Geology and Ground-Water Resources of North Dakota, U. S. Geological Survey Water Supply Paper 598, p. 225, 1929.

27A. pp. 144-145

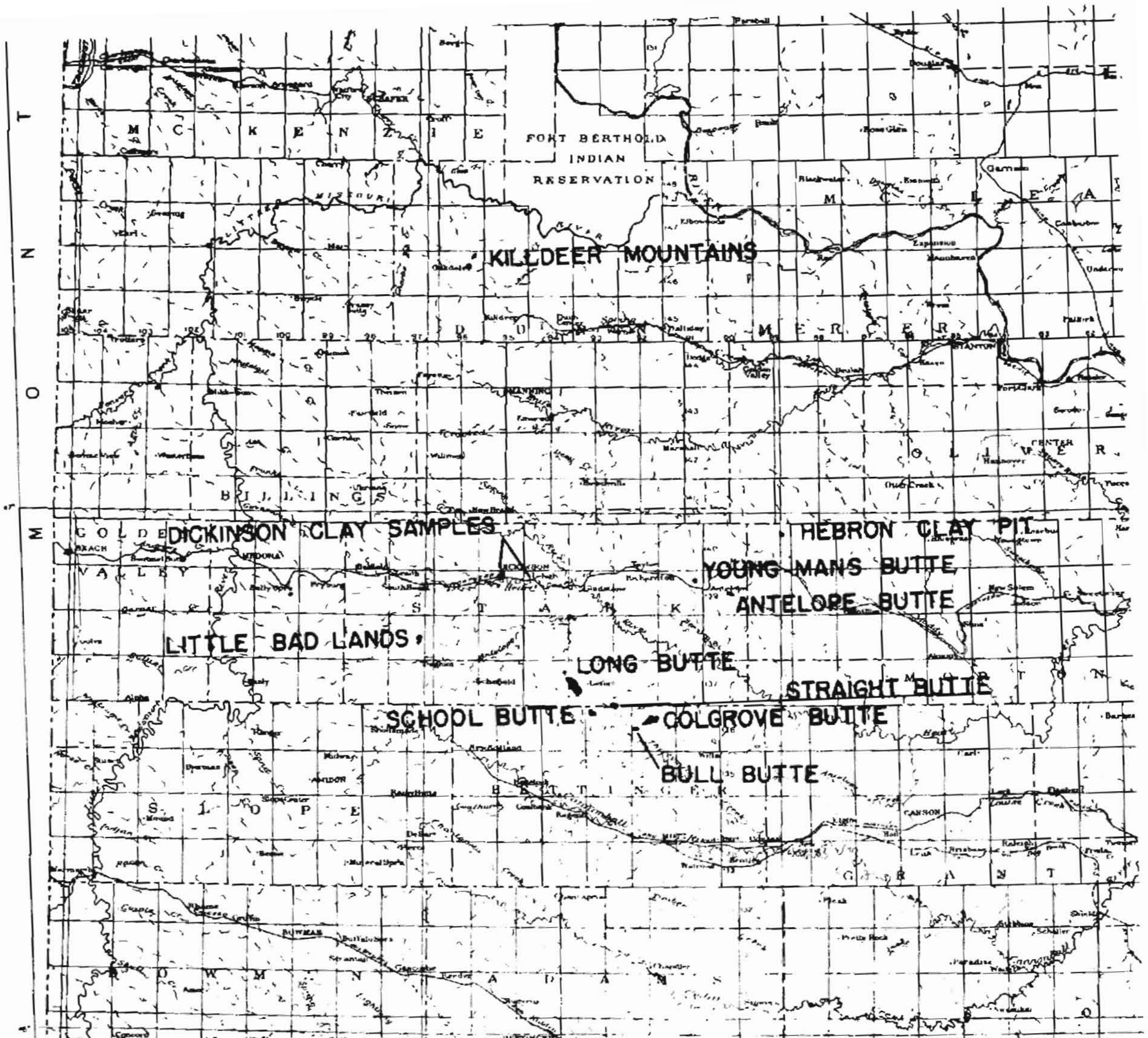
28. Thorsteinsson, T. Preliminary Report on the Geology of Colgrove Butte, Hettinger County, North Dakota, 1949, unpublished M. A. Thesis, Geology Department of University of North Dakota.

29. Wanless, H. R. Lithology of White River Sediments, Pro. Amer. Philos. Soc. Vol. 61, p. 195, 1922.

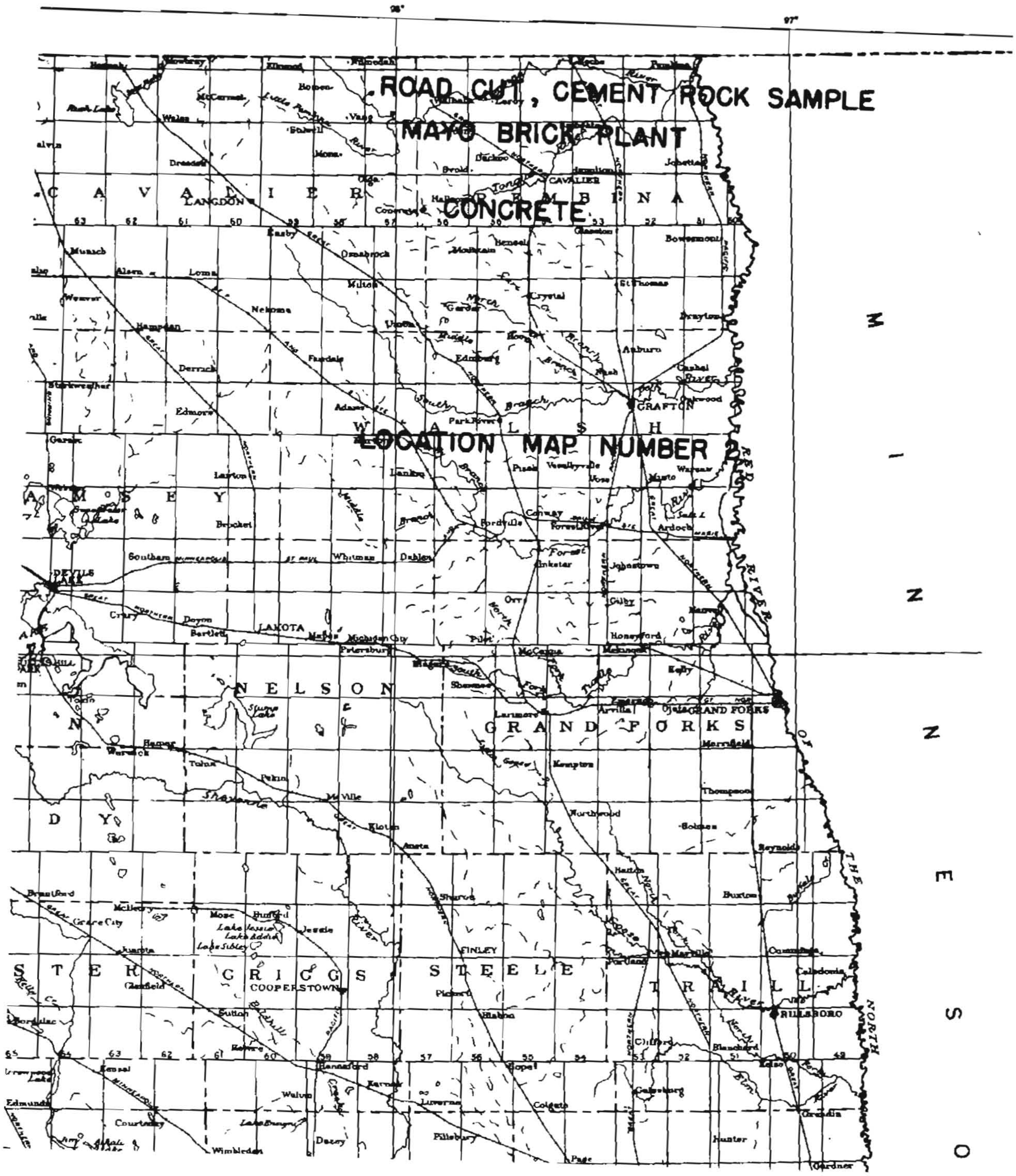
29A. pp. 195-202

30. Wanless, H. R. Stratigraphy of the White River Beds of South Dakota, Pro. Amer. Philos. Soc. Vol. 62, No. 4, p. 218, 1923.

31. White, C. A. Reference from Leonard, A. G., Geology of Southwestern North Dakota, North Dakota Geological Survey, Fifth Biennial Report, pp. 64-65, 1908.



LOCATION MAP NUMBER I


ROAD CUT, CEMENT ROCK SAMPLE
MAYO BRICK PLANT
CONCRETE
LOCATION MAP NUMBER 2
CAVALIER
PEMBINA
WALSH
GRAND FORKS
NELSON
RAMSEY
TRAILL
STEELE
GRIGGS
LANGDON
CAVALIER
GRAFTON
GRAND FORKS
DEVILS LAKE
LAKOTA
COOPERSTOWN
HILLSBORO
FINLEY
MINNESOTA
RED RIVER OF THE NORTH
98°
97°

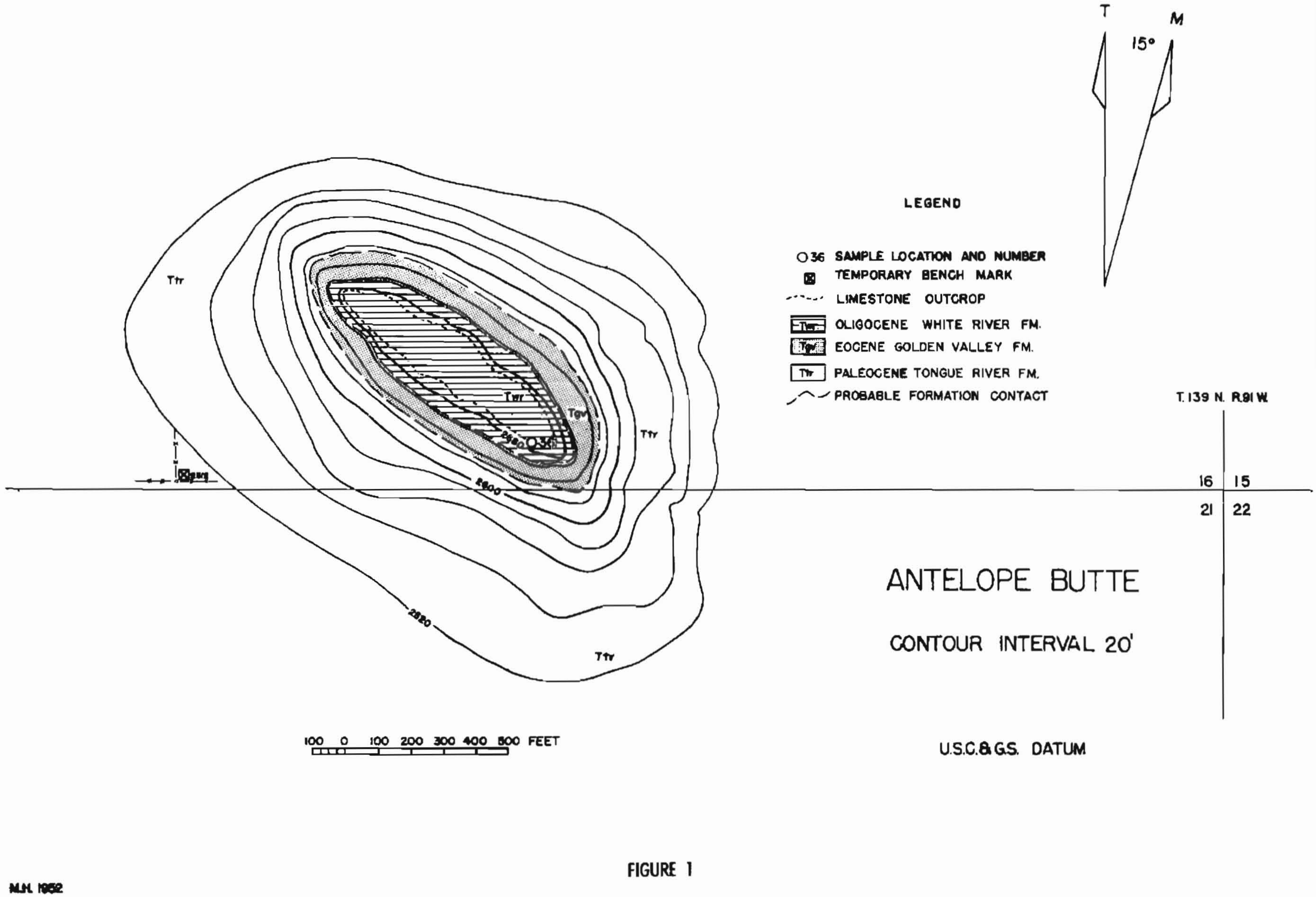

T
M
15°
LEGEND
O 36 SAMPLE LOCATION AND NUMBER
TEMPORARY BENCH MARK
LIMESTONE OUTCROP
Twr OLIGOCENE WHITE RIVER FM.
Tgv EOCENE GOLDEN VALLEY FM.
Ttr PALEOCENE TONGUE RIVER FM.
PROBABLE FORMATION CONTACT
T. 139 N. R.91 W.
16
15
21
22
Ttr
Twr
Tgv
2800
2820
ANTELOPE BUTTE
CONTOUR INTERVAL 20'
100 0 100 200 300 400 500 FEET
U.S.C.& G.S. DATUM
M.H. 1952

FIGURE 1

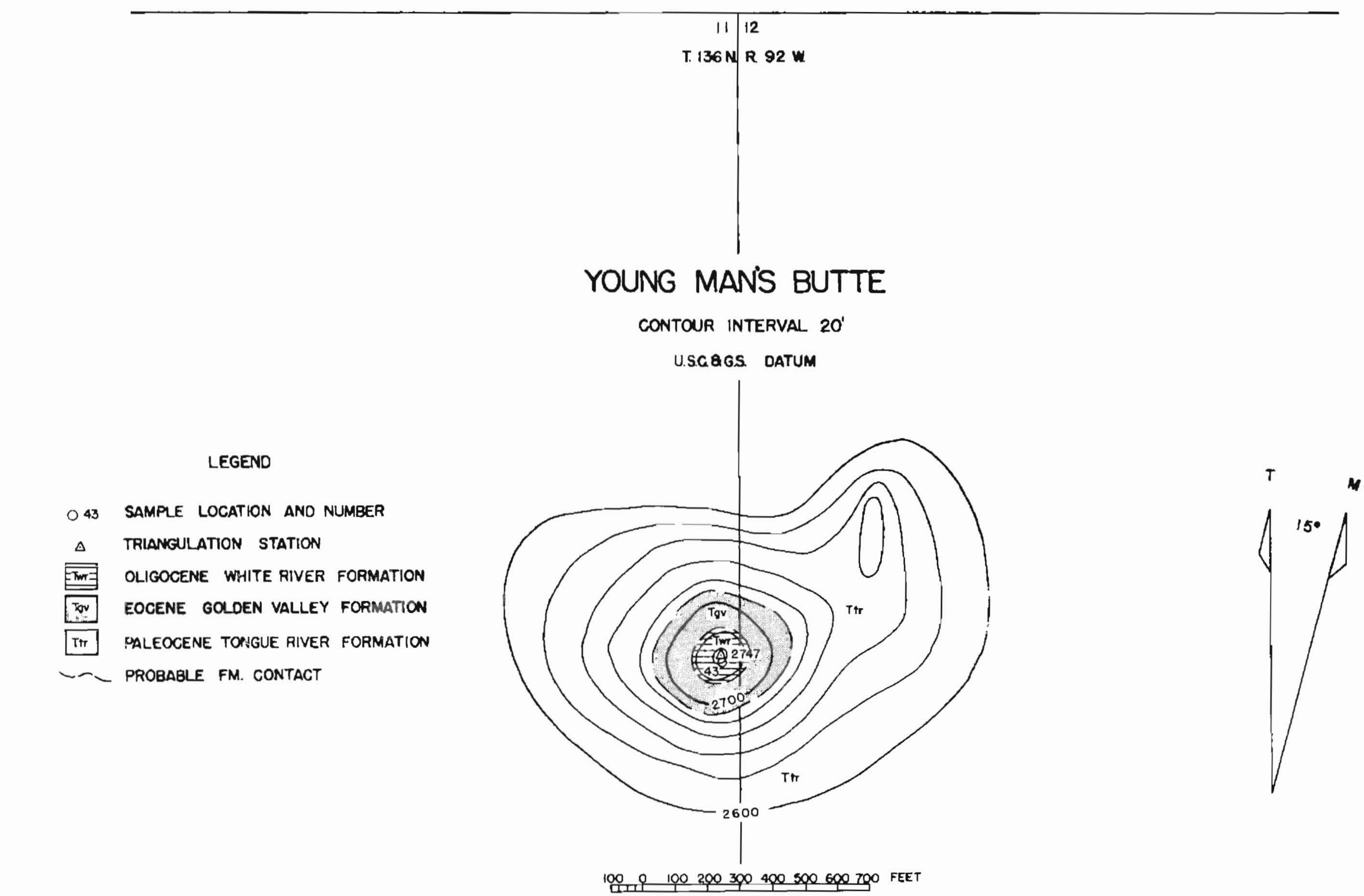
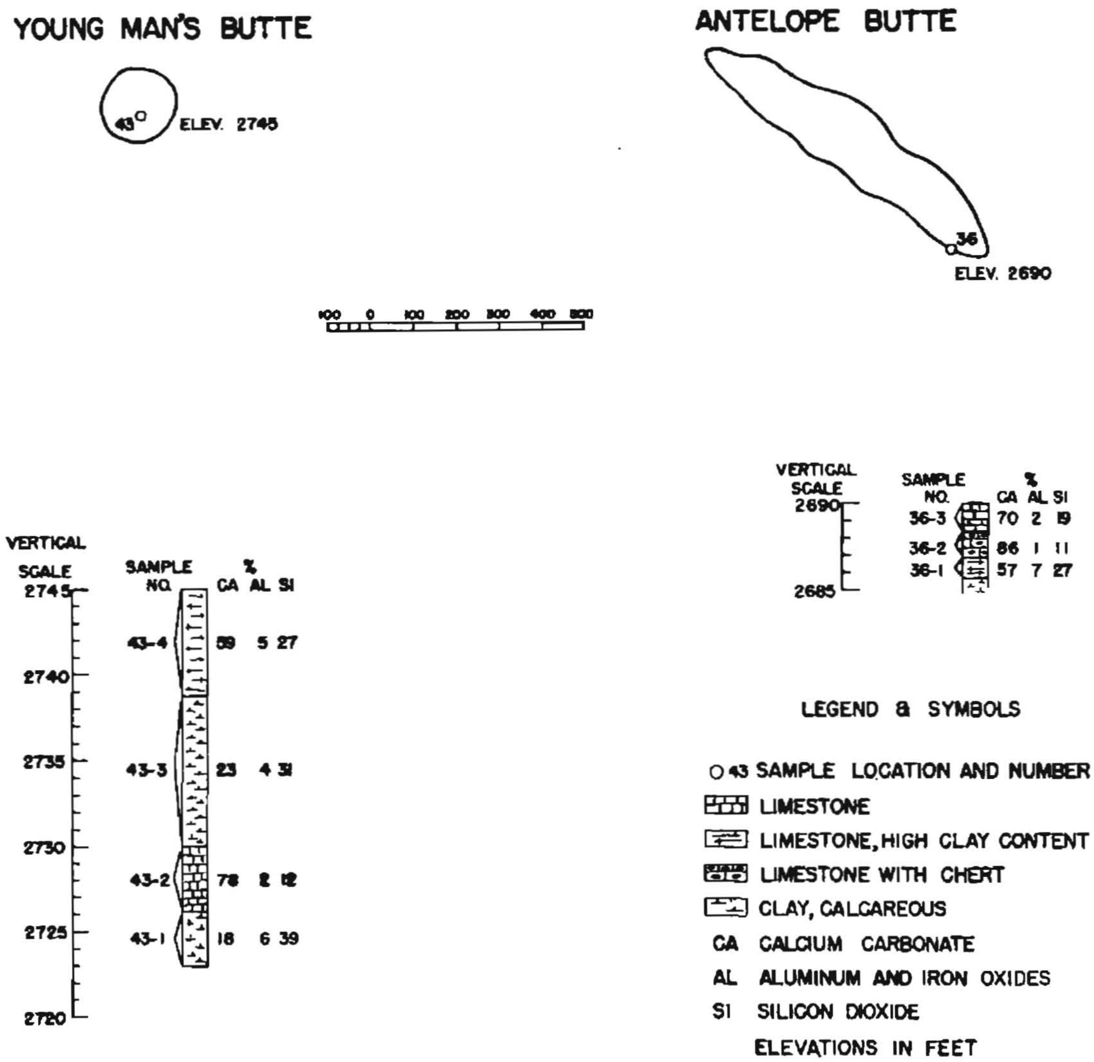


FIGURE 2

M.H. 1952



ASSAY CROSS SECTIONS

FIGURE 3

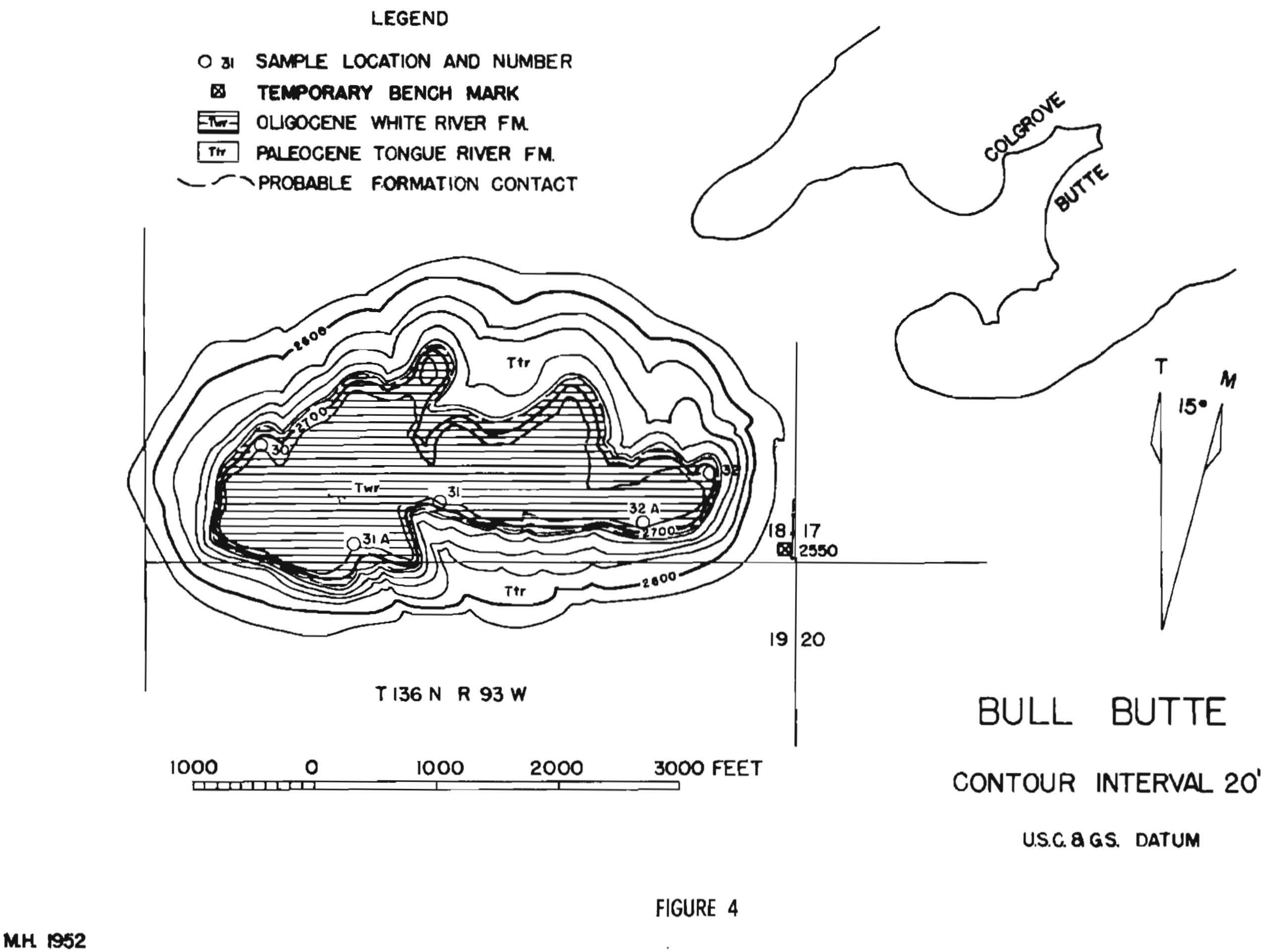
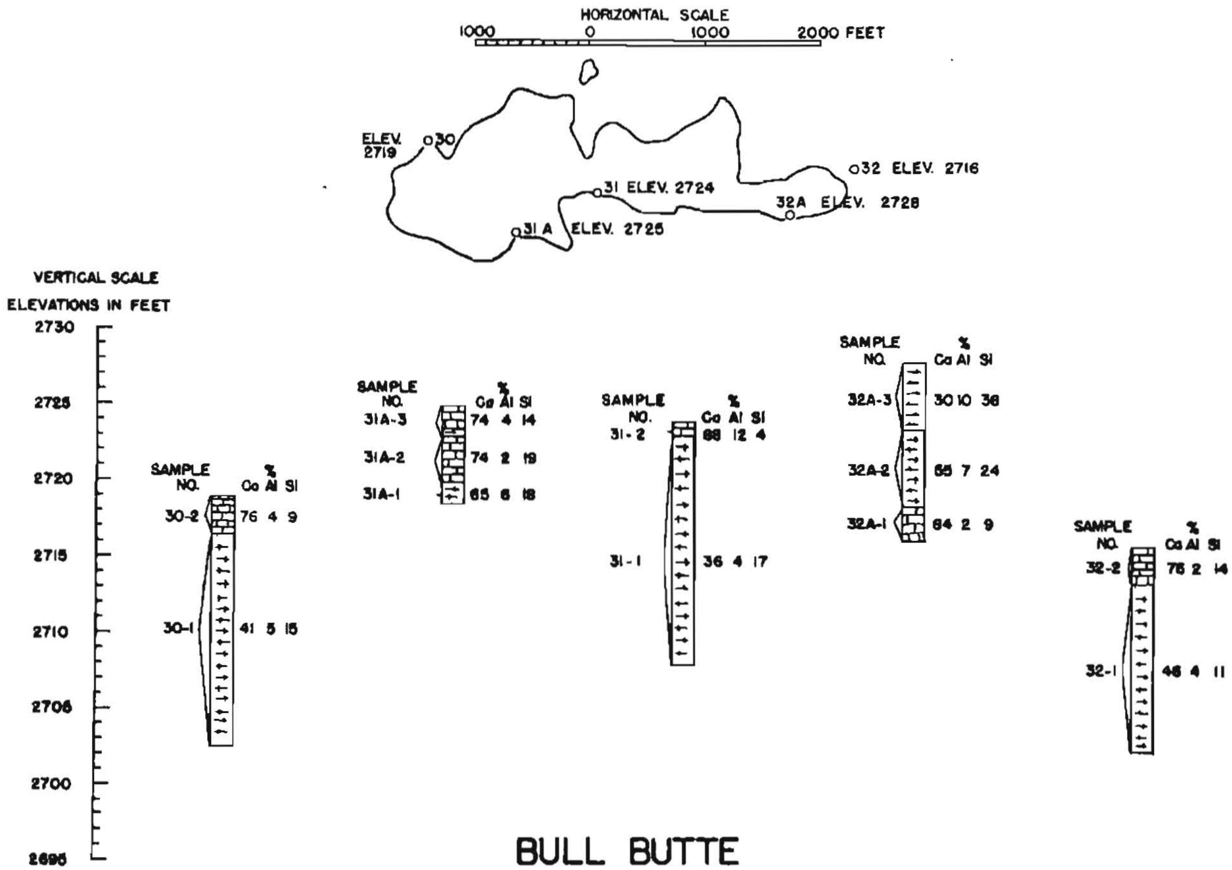

LEGEND
O 31 SAMPLE LOCATION AND NUMBER
TEMPORARY BENCH MARK
Twr OLIGOCENE WHITE RIVER FM.
Ttr PALEOCENE TONGUE RIVER FM.
PROBABLE FORMATION CONTACT
COLGROVE
BUTTE
2600
2700
Ttr
Twr
30
31
31 A
32
32 A
18
17
19
20
2550
T
M
15°
T 136 N R 93 W
1000 0 1000 2000 3000 FEET
BULL BUTTE
CONTOUR INTERVAL 20'
U.S.C. & G.S. DATUM
M.H. 1952

FIGURE 4



BULL BUTTE

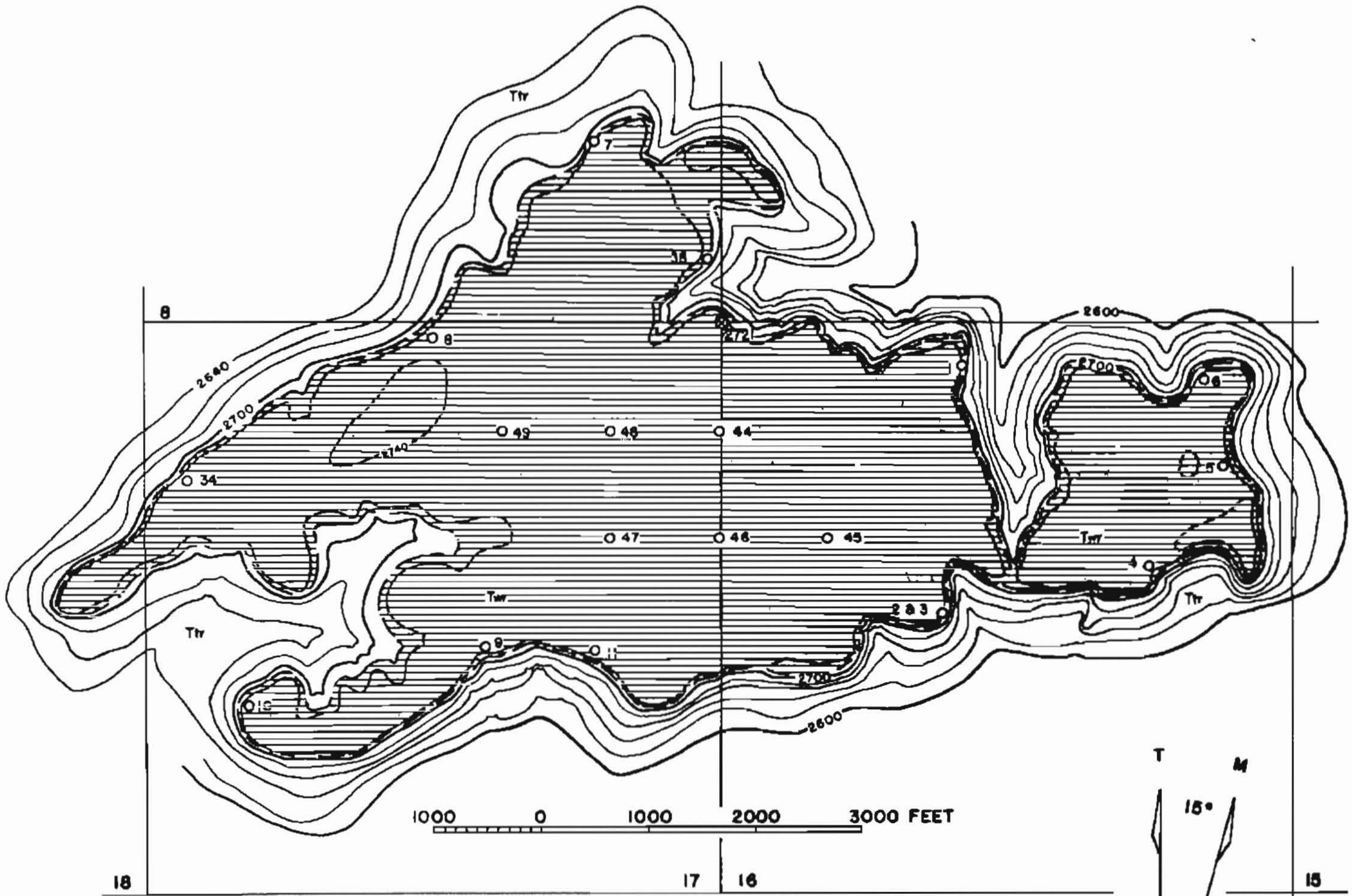
ASSAY CROSS SECTIONS

LEGEND & SYMBOLS

- o SAMPLE LOCATION AND NUMBER
- LIMESTONE
- LIMESTONE, HIGH CLAY CONTENT
- CALCAREOUS CLAY
- Ca CALCIUM CARBONATE
- Al ALUMINUM & IRON OXIDES
- Si SILICON DIOXIDE

M.H., 1952

FIGURE 5



LEGEND

O 10 SAMPLE LOCATION AND NUMBER

■ TEMPORARY BENCH MARK

Twr OLIGOCENE WHITE RIVER FORMATION

Ttr PALEOCENE TONGUE RIVER FORMATION

PROBABLE FORMATION CONTACT

COLGROVE BUTTE

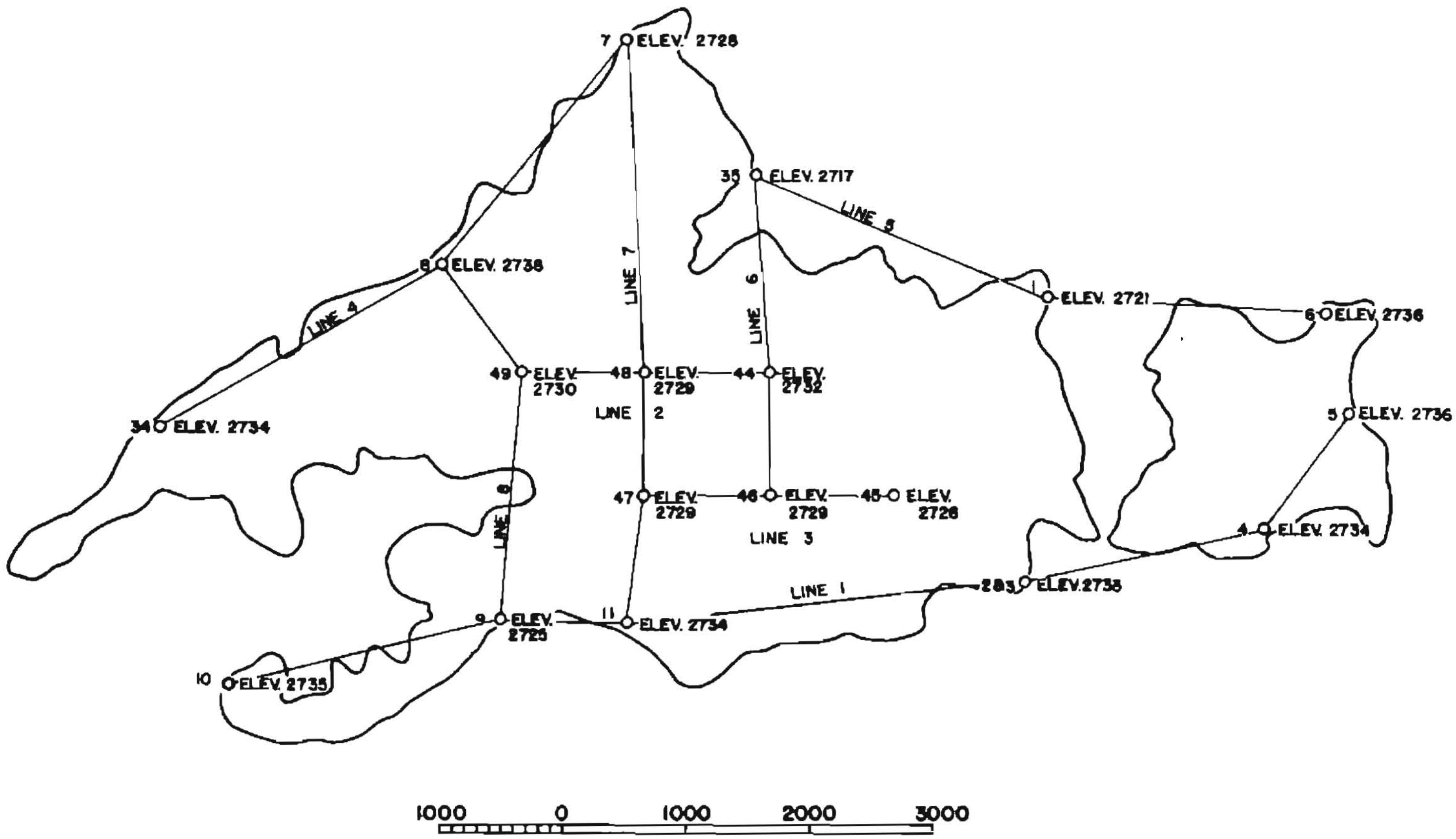
CONTOUR INTERVAL 20'

U.S.C.&G.S. DATUM

T. 136 N. R. 93 W.

FIGURE 6

MH. 1962



LEGEND & SYMBOLS

- TOP SOIL
- LIMESTONE
- LIMESTONE, HIGH CLAY CONTENT
- LIMESTONE WITH CHERT
- CLAY
- CALCAREOUS CLAY
- SAND
- O 10 SAMPLE LOCATION AND NUMBER

COLGROVE BUTTE

LINES OF ASSAY CROSS SECTIONS

SHEET 1 OF 4

ASSAY SYMBOLS

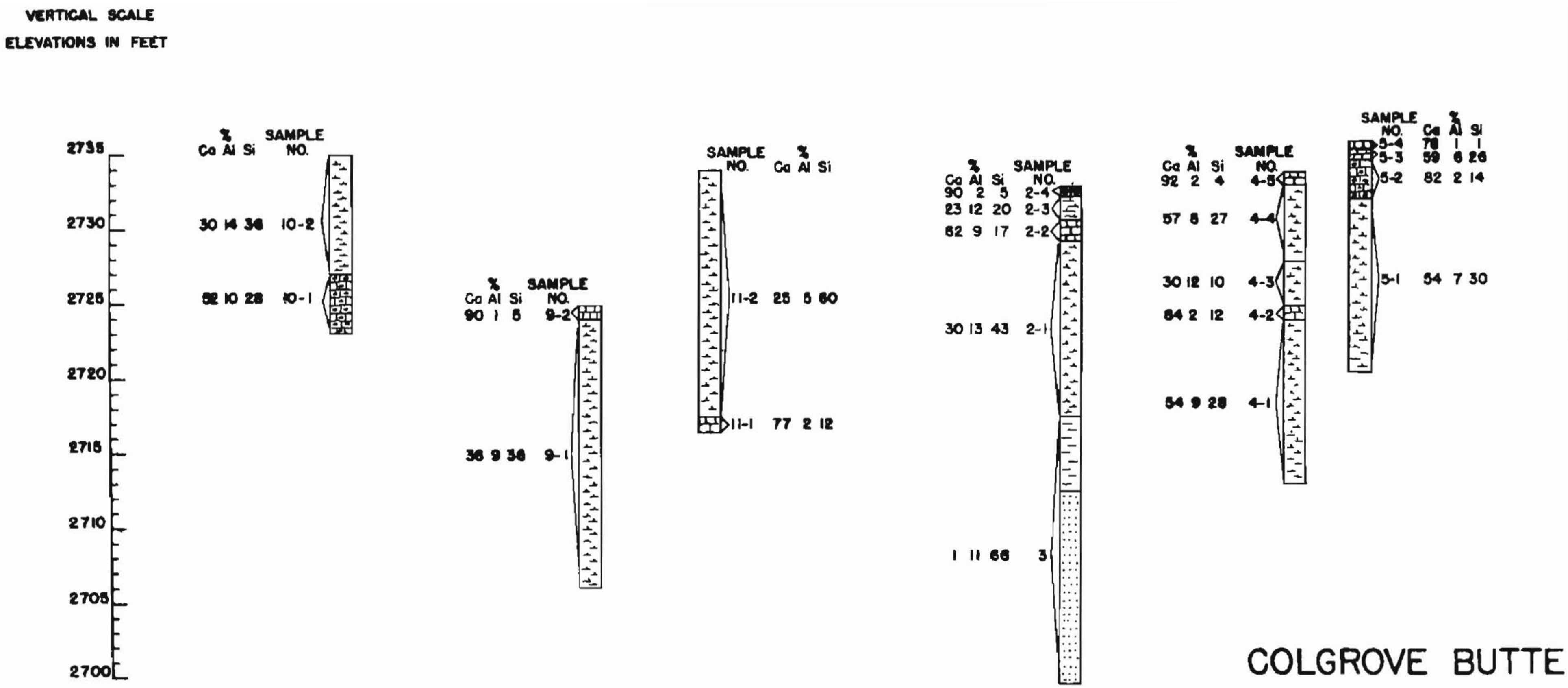
Ca CALCIUM CARBONATE

Al ALUMINUM & IRON OXIDES

Si SILICON DIOXIDE

M.H., 1952

FIGURE 7



COLGROVE BUTTE
ASSAY CROSS SECTIONS
LINE I

SHEET 2 OF 4

SEE SHEET I FOR LEGEND & SYMBOLS

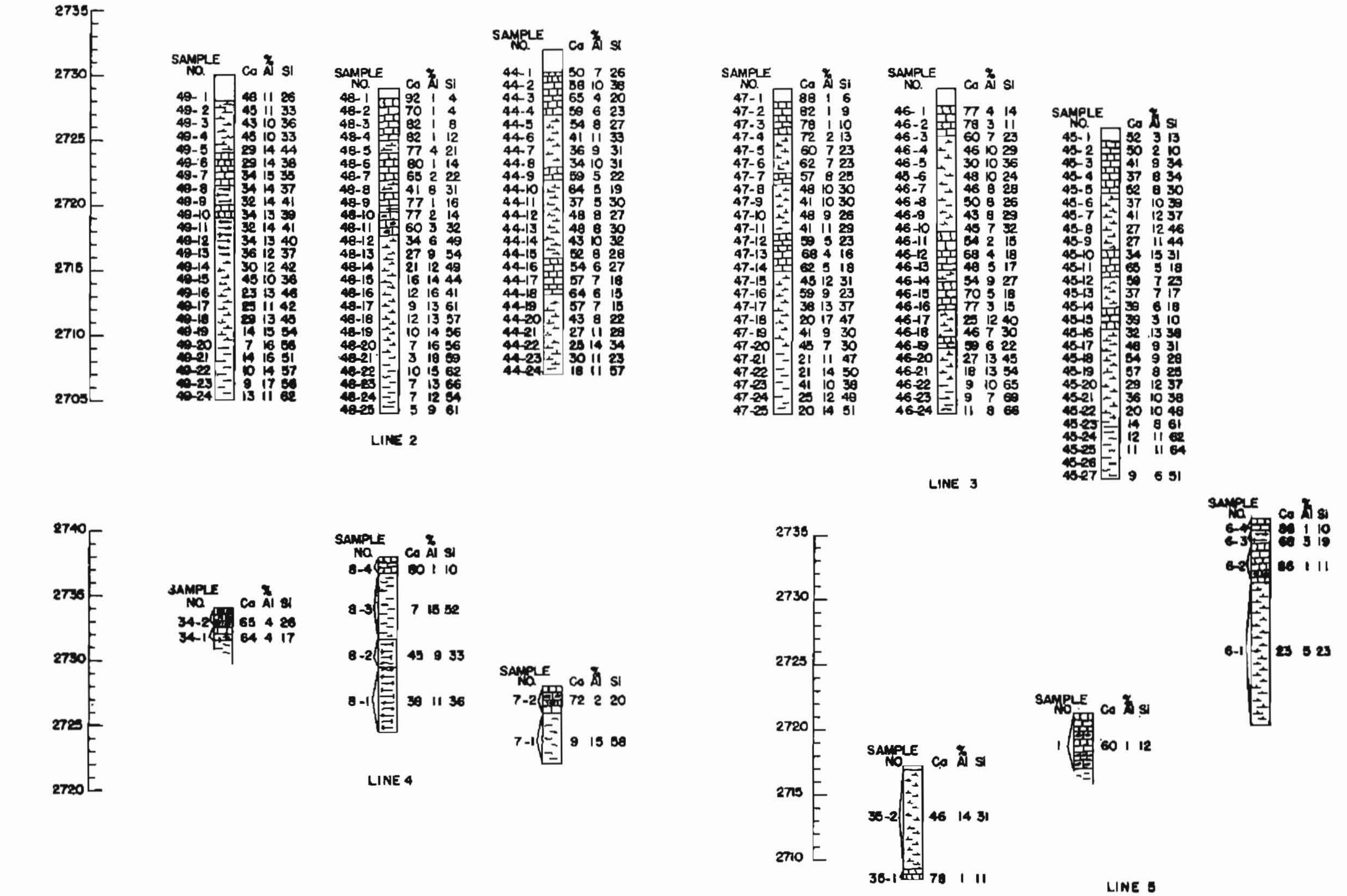
FIGURE 7A

.H., 1962

COLGROVE BUTTE

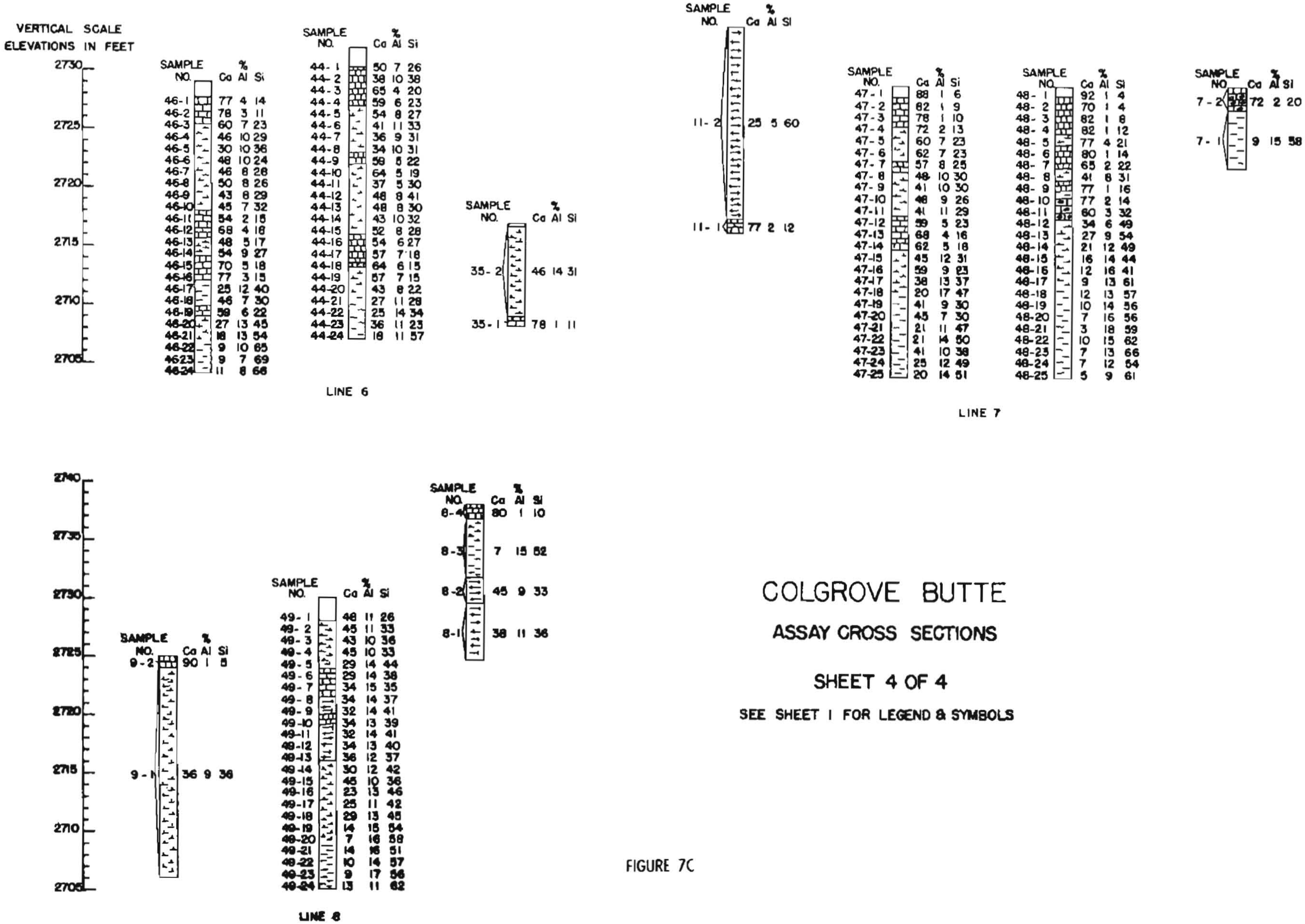
ASSAY CROSS SECTIONS

SHEET 3 OF 4



SEE SHEET 1 FOR LEGEND & SYMBOLS

FIGURE 7B



COLGROVE BUTTE

ASSAY CROSS SECTIONS

SHEET 4 OF 4

SEE SHEET 1 FOR LEGEND & SYMBOLS

FIGURE 7C

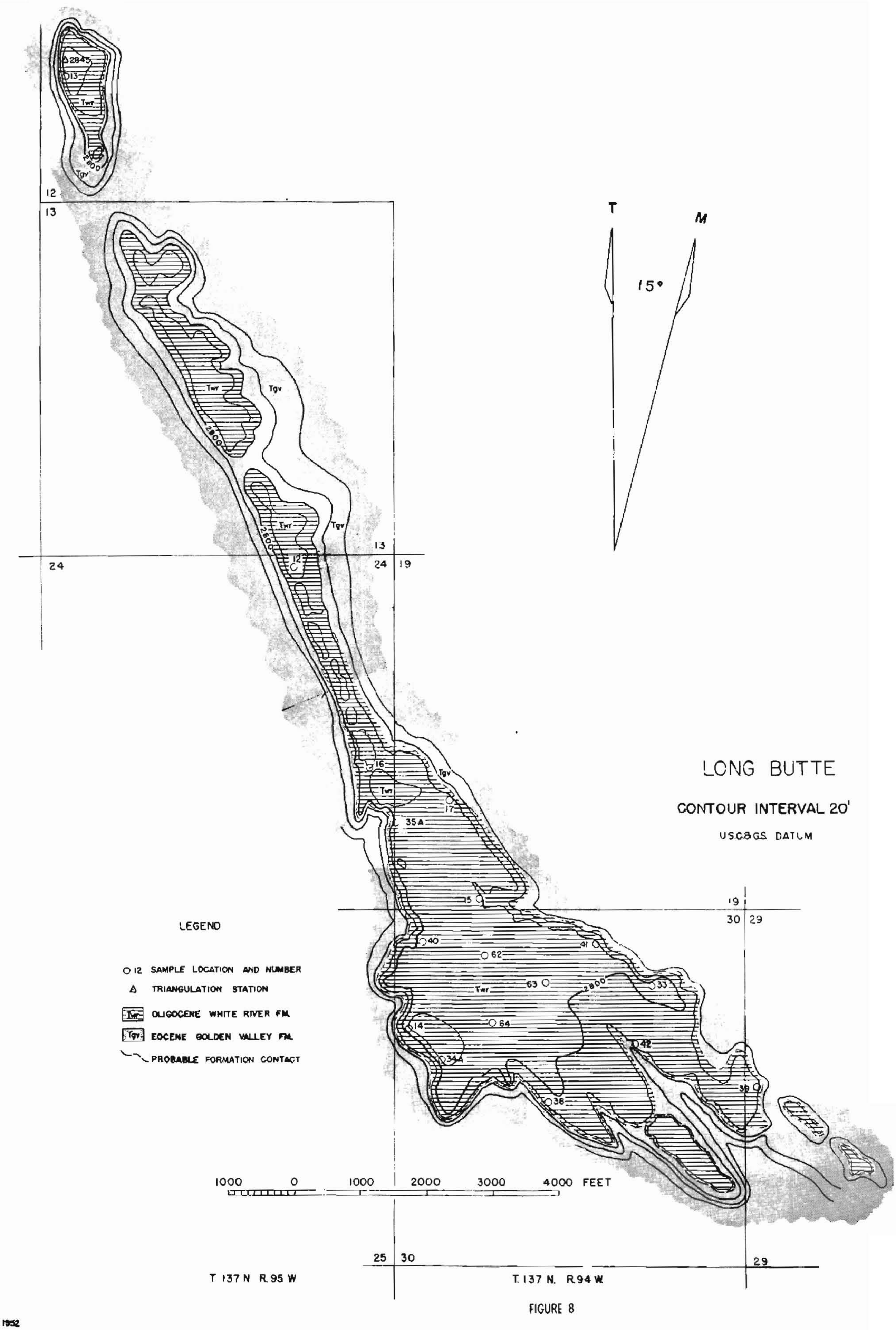

LONG BUTTE
CONTOUR INTERVAL 20'
U.S.C.& G.S. DATUM
LEGEND
O 12 SAMPLE LOCATION AND NUMBER
Δ TRIANGULATION STATION
Twr OLIGOCENE WHITE RIVER FM.
Tgv EOCENE GOLDEN VALLEY FM.
PROBABLE FORMATION CONTACT
T
M
15°
1000 0 1000 2000 3000 4000 FEET
T 137 N R 95 W
T. 137 N. R. 94 W.
M.H. 1952

FIGURE 8

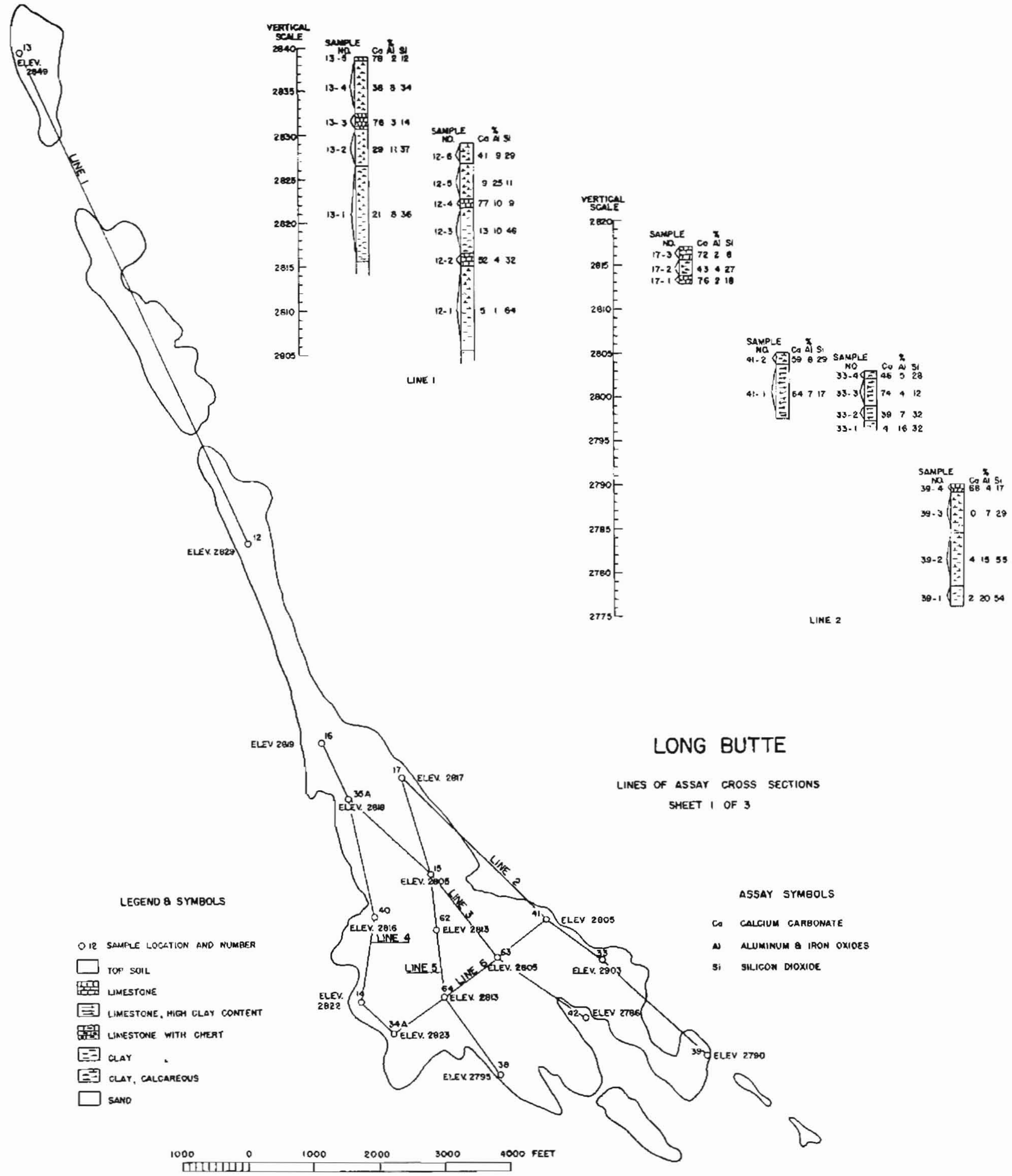
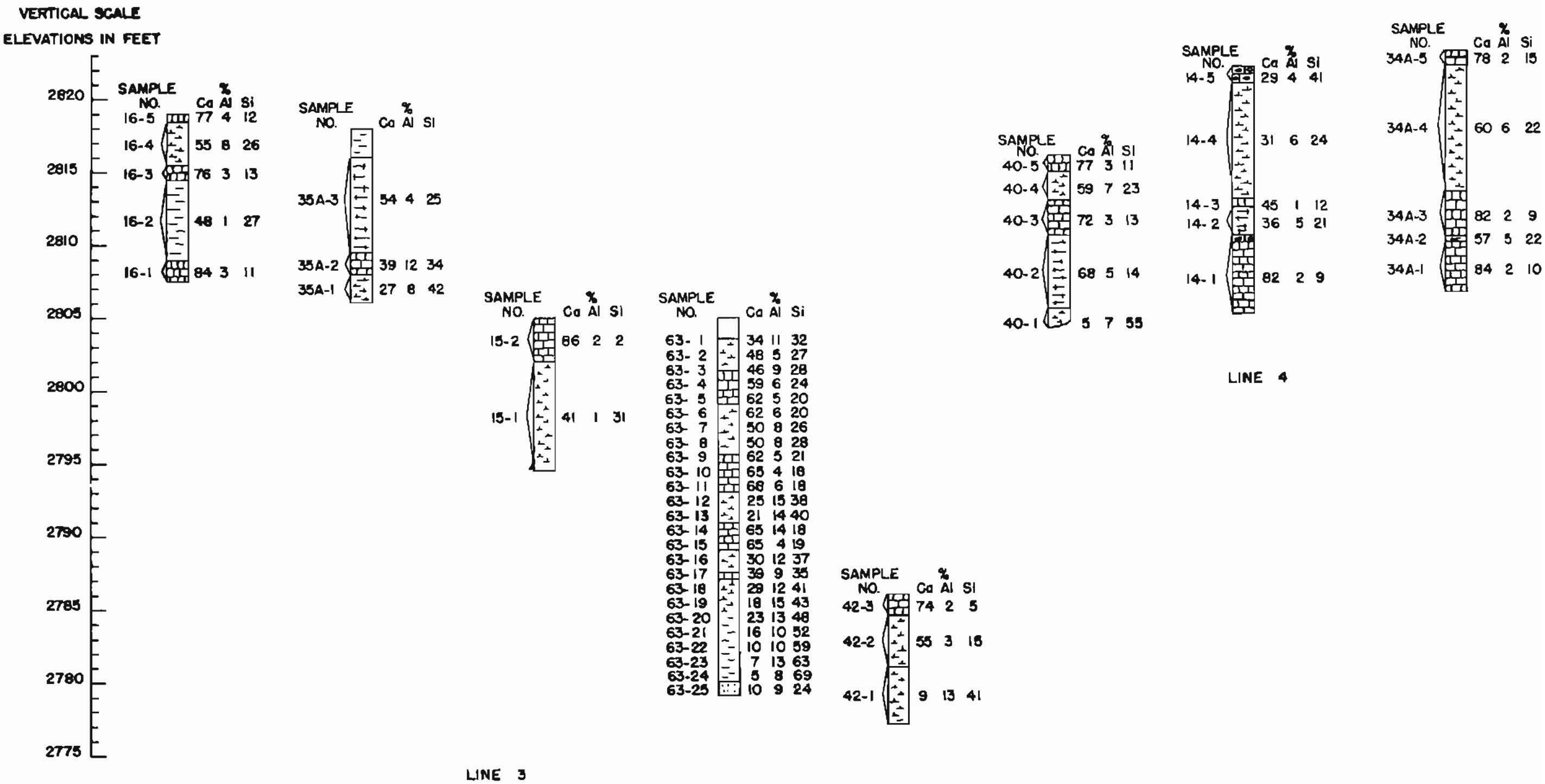


FIGURE 9

M.H., 1962



LONG BUTTE

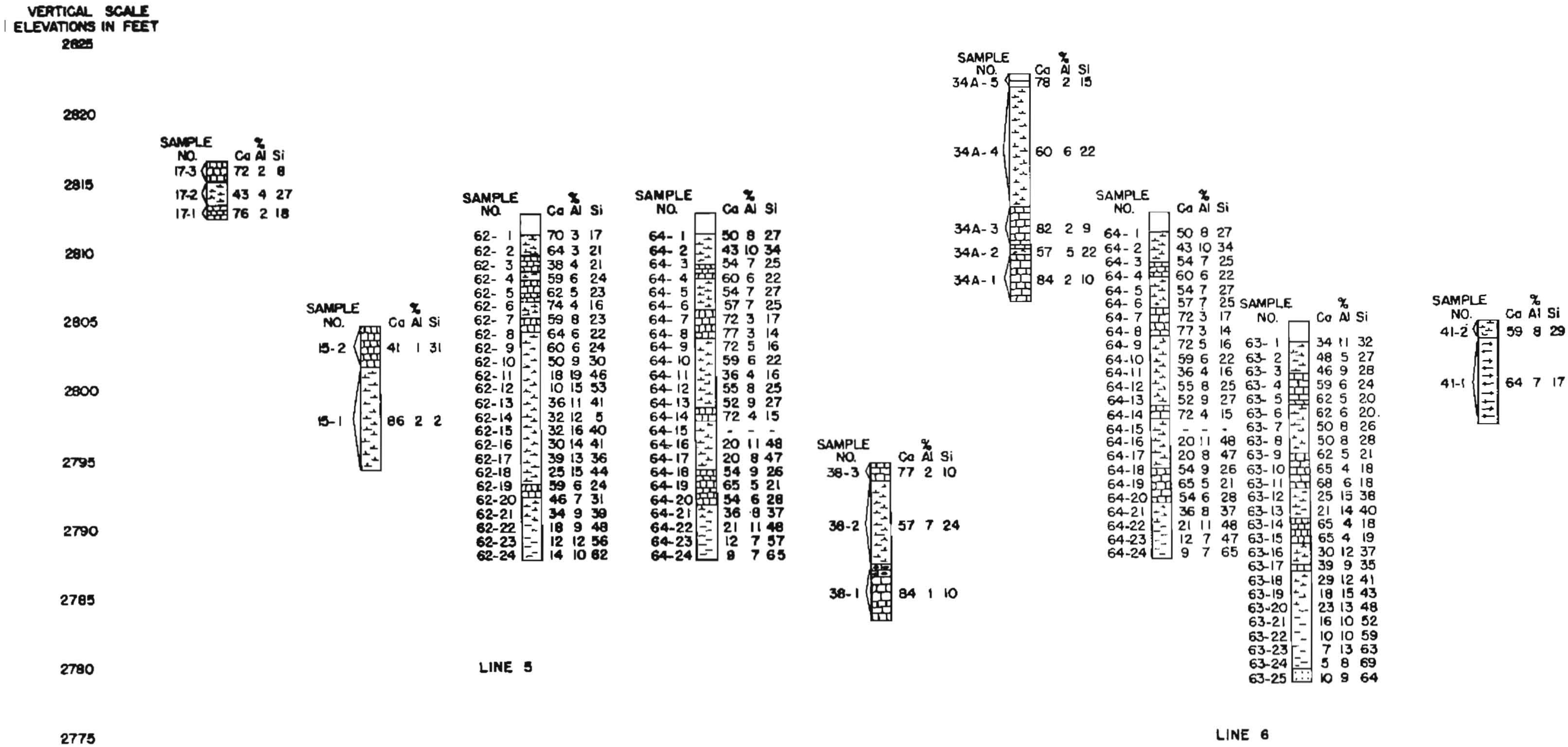
ASSAY CROSS SECTIONS

SHEET 2 OF 3

LEGEND & SYMBOLS ON SHEET I

FIGURE 9A

M.H.,1952



LONG BUTTE

ASSAY CROSS SECTIONS

SHEET 3 OF 3

LEGEND & SYMBOLS ON SHEET I

FIGURE 9B

M.H., 1952

LEGEND

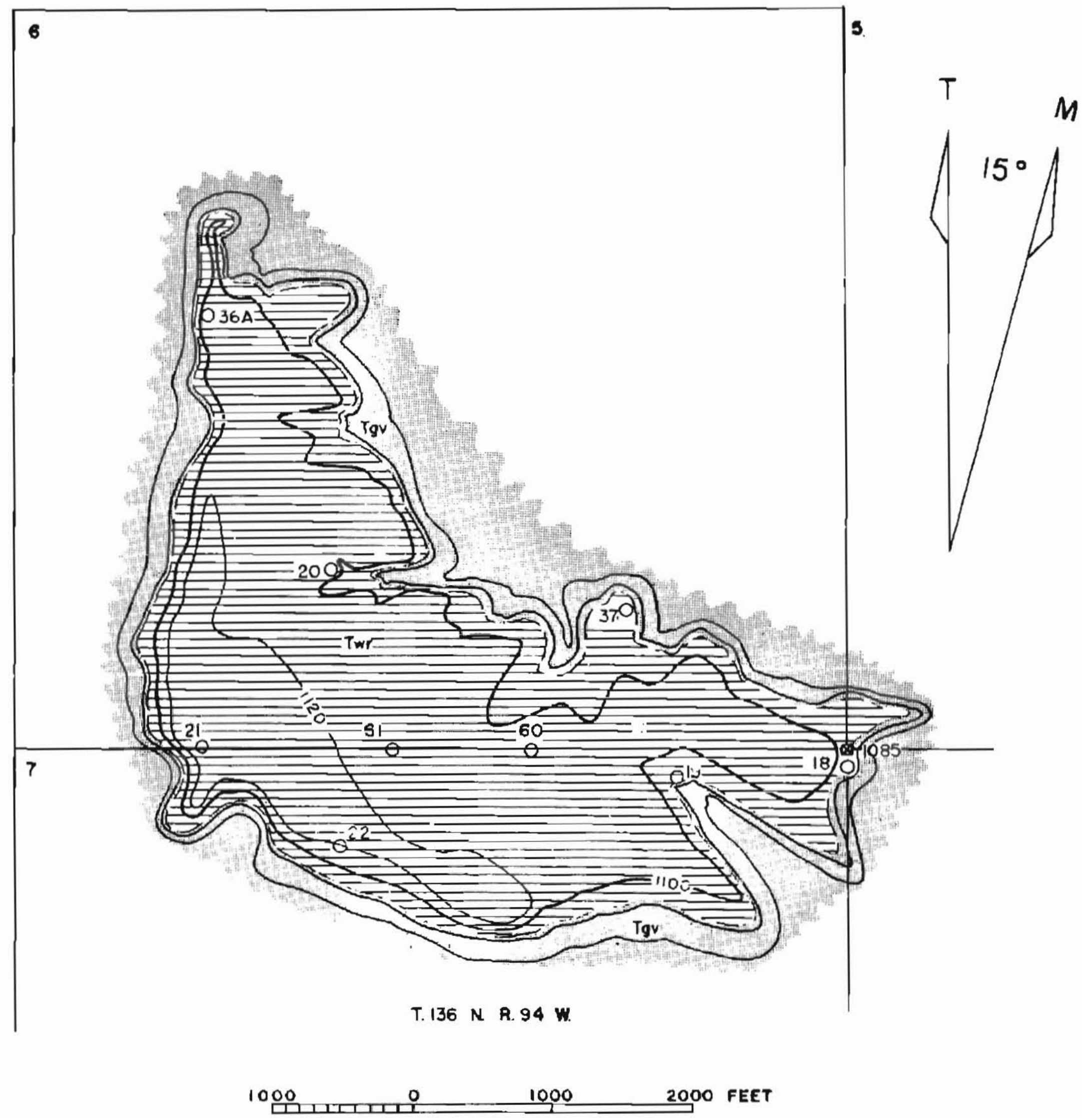
○ 20 SAMPLE LOCATION AND NUMBER

⊠ TEMPORARY BENCH MARK

Twr OLIGOCENE WHITE RIVER FORMATION

Tgv EOCENE GOLDEN VALLEY FORMATION

PROBABLE FORMATION CONTACT



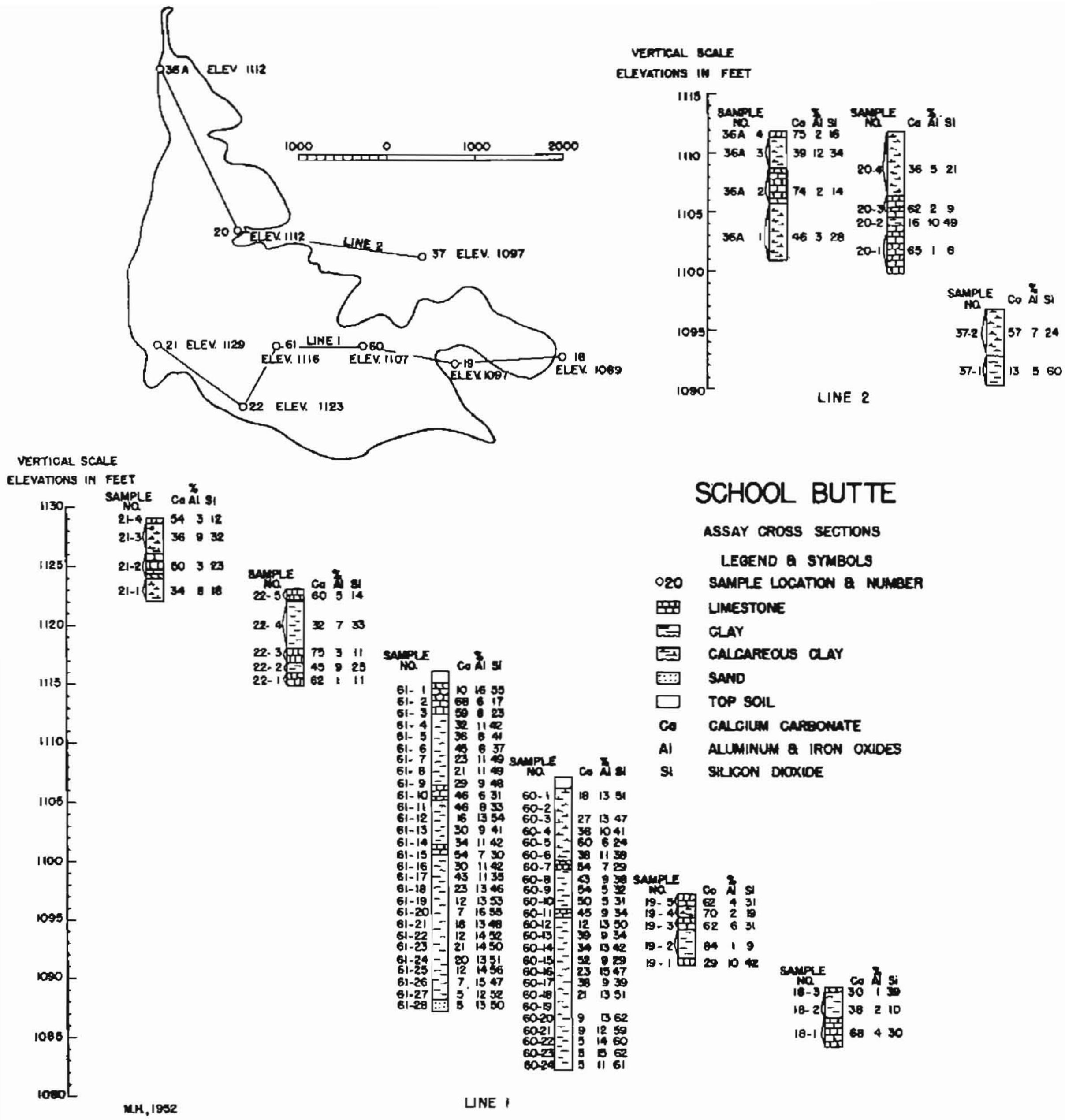
SCHOOL BUTTE

CONTOUR INTERVAL 20'

ASSUMED DATUM

FIGURE 10

M.H. 1952



36A ELEV. 1112
1000 0 1000 2000
20 ELEV. 1112
LINE 2
37 ELEV. 1097
21 ELEV. 1129
61 LINE 1 60
ELEV. 1116
ELEV. 1107
19 ELEV. 1097
18 ELEV. 1089
22 ELEV. 1123
VERTICAL SCALE
ELEVATIONS IN FEET
LINE 2
LINE 1
SCHOOL BUTTE
ASSAY CROSS SECTIONS
LEGEND & SYMBOLS
○20 SAMPLE LOCATION & NUMBER
LIMESTONE
CLAY
CALCAREOUS CLAY
SAND
TOP SOIL
Ca CALCIUM CARBONATE
Al ALUMINUM & IRON OXIDES
Si SILICON DIOXIDE
SAMPLE NO. % Ca Al Si
M.H., 1952

FIGURE 11

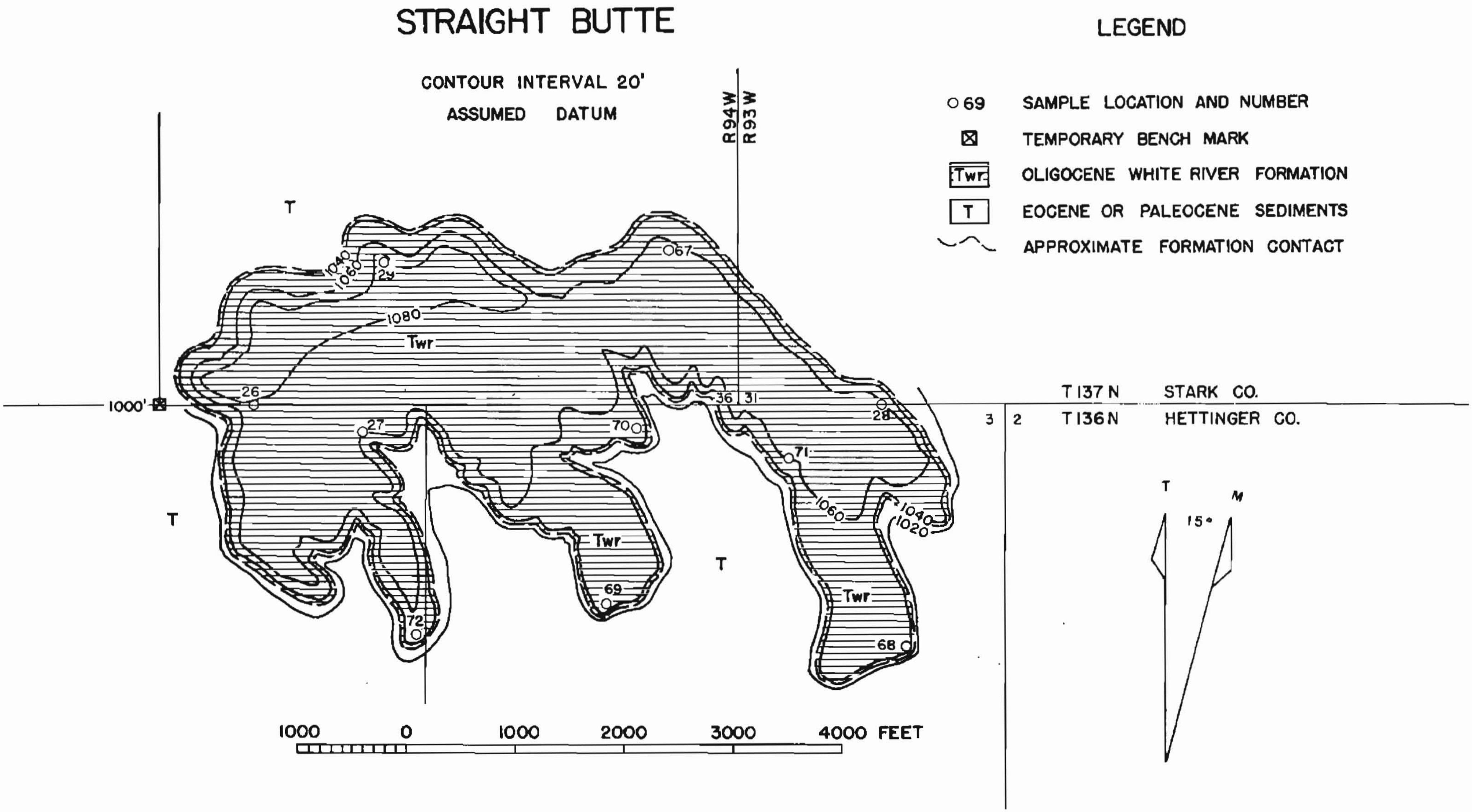


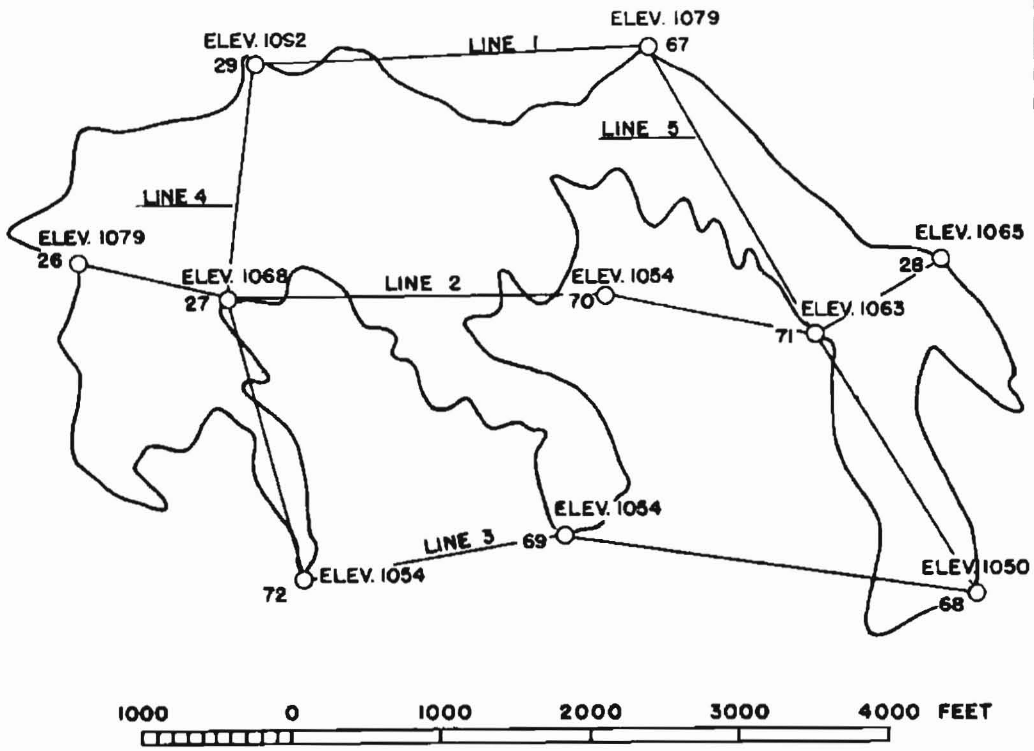
FIGURE 12

M.H., 1952

STRAIGHT BUTTE

LINES OF ASSAY CROSS SECTIONS

SHEET 1 OF 3



LEGEND

○ 69 SAMPLE LOCATION AND NUMBER

TOP SOIL

LIMESTONE

LIMESTONE, HIGH CLAY CONTENT

LIMESTONE, WITH CHERT

CLAY, CALCAREOUS

ASSAY SYMBOLS

Ca CALCIUM CARBONATE

Al ALUMINUM & IRON OXIDES

Si SILICON DIOXIDE

FIGURE 13

M.H., 1952

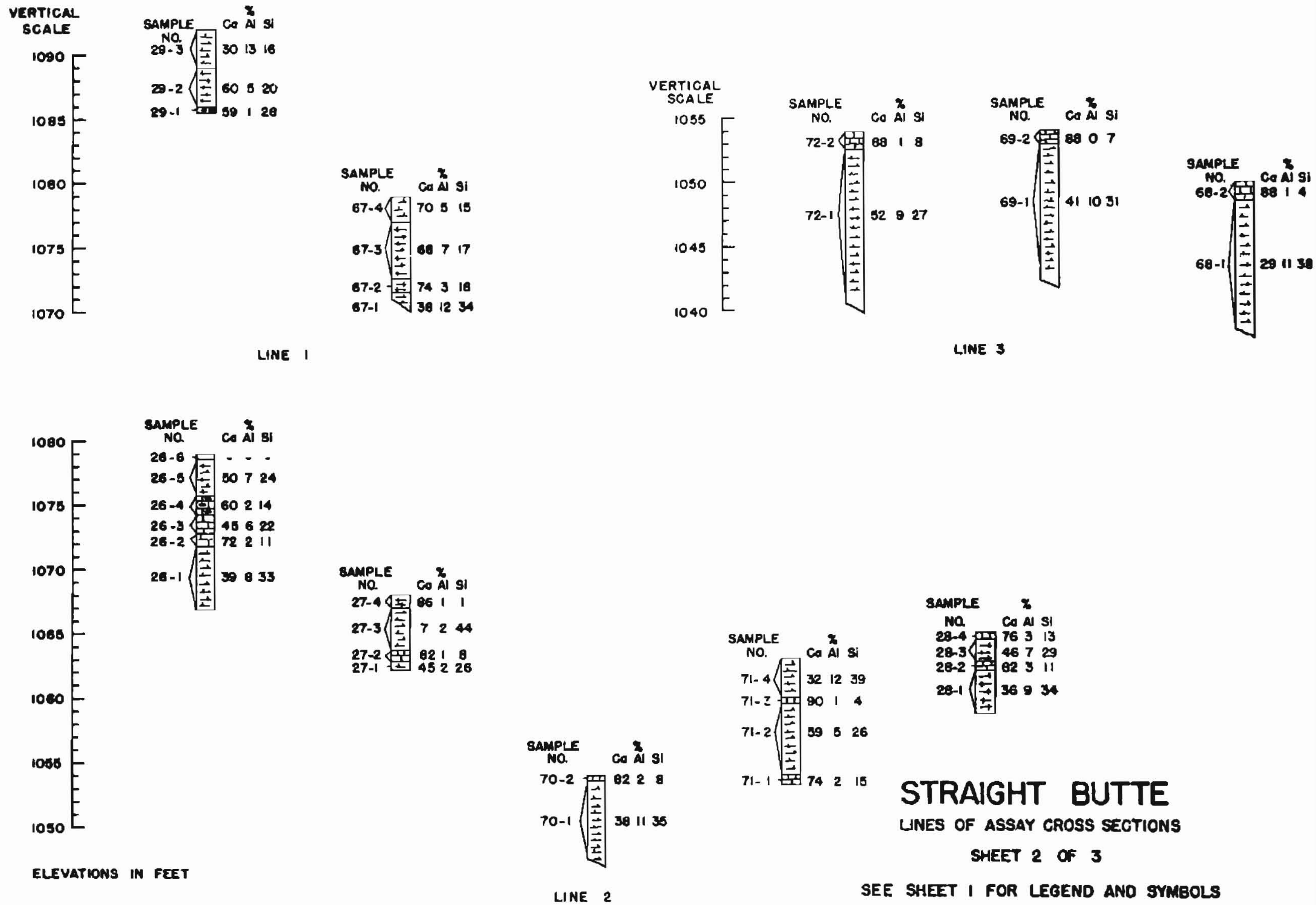


FIGURE 13A

M.H.,1952

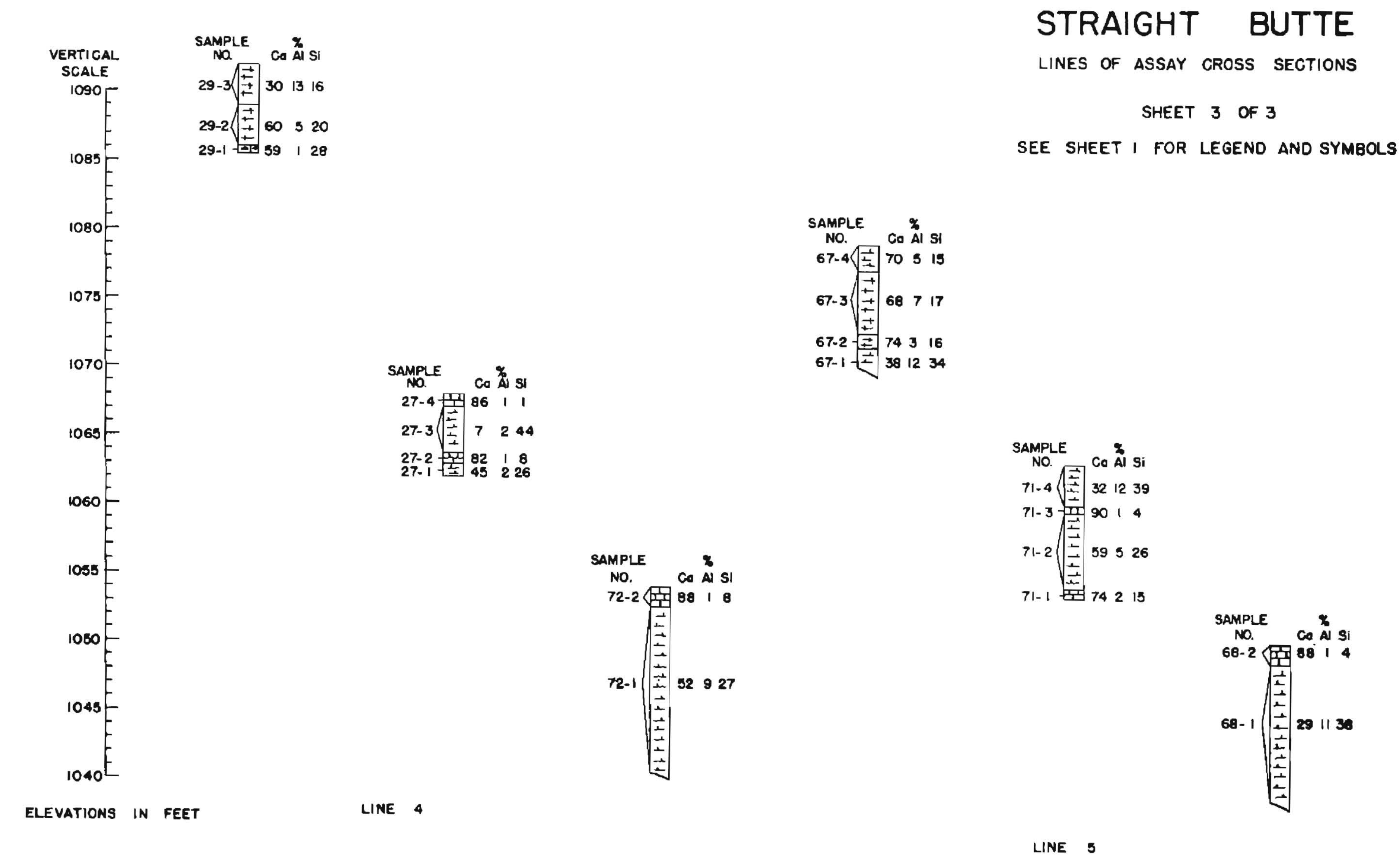
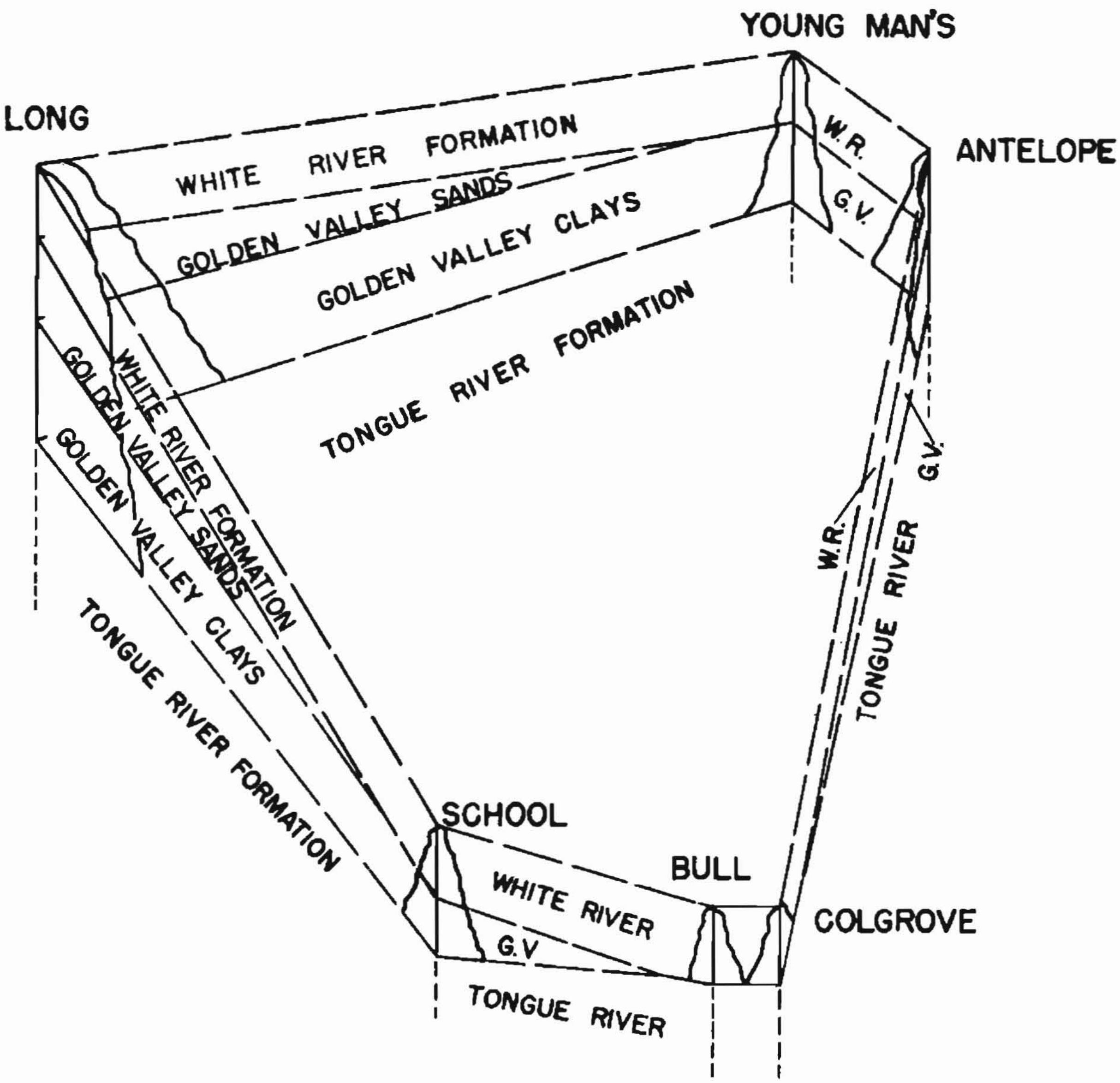


FIGURE 13B

M.H., 1952



AREAL CORRELATIONS OF TERTIARY SEDIMENTS

M.H., 1952

FIGURE 14

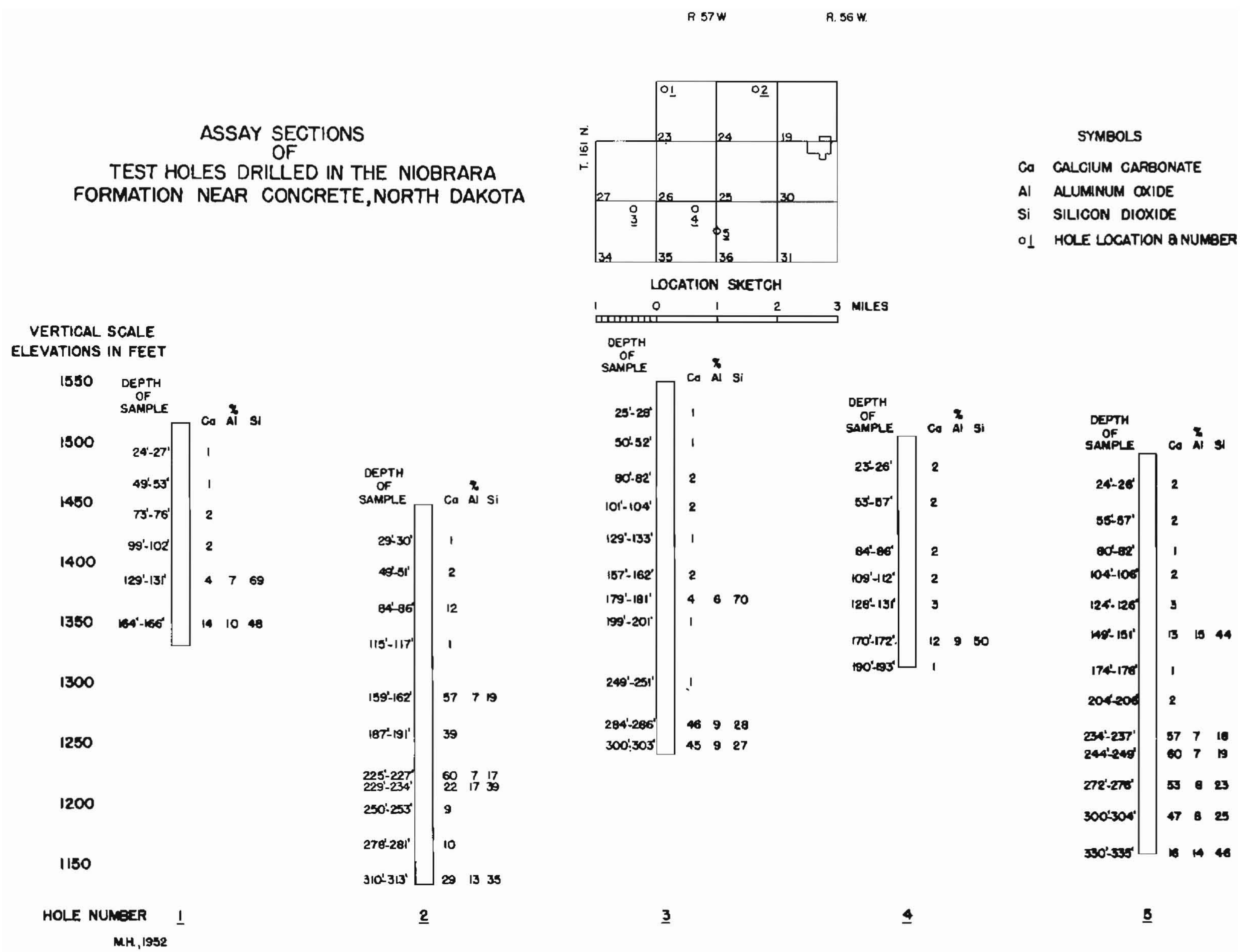

ASSAY SECTIONS OF TEST HOLES DRILLED IN THE NIOBRARA FORMATION NEAR CONCRETE, NORTH DAKOTA
R 57 W
R. 56 W.
T. 161 N.
LOCATION SKETCH
1 0 1 2 3 MILES
SYMBOLS
Ca CALCIUM CARBONATE
Al ALUMINUM OXIDE
Si SILICON DIOXIDE
o1 HOLE LOCATION & NUMBER
VERTICAL SCALE
ELEVATIONS IN FEET
1550
1500
1450
1400
1350
1300
1250
1200
1150
DEPTH OF SAMPLE
% Ca Al Si
24'-27' 1
49'-53' 1
73'-76' 2
99'-102' 2
129'-131' 4 7 69
164'-166' 14 10 48
29'-30' 1
49'-51' 2
84'-86' 12
115'-117' 1
159'-162' 57 7 19
187'-191' 39
225'-227' 60 7 17
229'-234' 22 17 39
250'-253' 9
278'-281' 10
310'-313' 29 13 35
25'-28' 1
50'-52' 1
80'-82' 2
101'-104' 2
129'-133' 1
157'-162' 2
179'-181' 4 6 70
199'-201' 1
249'-251' 1
284'-286' 46 9 28
300'-303' 45 9 27
23'-26' 2
53'-57' 2
84'-86' 2
109'-112' 2
128'-131' 3
170'-172' 12 9 50
190'-193' 1
24'-26' 2
55'-57' 2
80'-82' 1
104'-106' 2
124'-126' 3
149'-151' 13 15 44
174'-176' 1
204'-206' 2
234'-237' 57 7 18
244'-249' 60 7 19
272'-276' 53 8 23
300'-304' 47 8 25
330'-335' 16 14 46
HOLE NUMBER 1 2 3 4 5
M.H., 1952

FIGURE 15