J H Hintze

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STRUCTURE AND STRATIGRAPHY OF THE LOWER AMERCIAN FORK CANYON–MAHOGANY MOUNTAIN AREA, UTAH COUNTY, UTAH

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STRUCTURE AND STRATIGRAPHY OF THE LOWER AMERICAN FORK CANYON-MAHOGANY MOUNTAIN AREA, UTAH COUNTY, UTAH

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submitted to

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Master of Science

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by

Richard F. Perkins

February, 1955

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TABLE OF CONTENTS

Page

ACKNOWLEDGMENTS iii

LIST OF ILLUSTRATIONS vi

ABSTRACT vii

INTRODUCTION
- Location 1
- Physical features 1
- Accessibility 3
- Summary of previous investigations 3
- Field and laboratory studies 5

GENERAL GEOLOGY
- Principal features 6
- Sedimentary rocks 8
  - General section 8
    - Cambrian System
      - Tintic Quartzite 8
      - Ophir Formation 9
      - Hartmann Limestone 13
      - Bowman Limestone 13
  - Pre-Lower Mississippian unconformity 14
    - Mississippian System
      - Gardner Formation 14
      - Deseret Limestone 15
      - Humbug Formation 16
      - Great Blue Limestone 17
    - Mississippian-Pennsylvania System
      - Manning Canyon Shale 18
    - Quaternary System
      - Pre-Lake Bonneville Fanglomerate 19
      - Lake Bonneville Sediments 19
      - Alluvium 19
- Geologic structure
  - General statement 19
    - Folds
      - Sagebrush Flat Flexure 20
      - Cattle Creek Folds 20
      - Drag Folds 21
      - Grove Creek Anticline 24

Faults. 24
Wasatch Fault System 24
Cattle Creek System 24
Mahogany Mountain Fault System 27
Burned Canyon Reverse Fault System 29
Date of folding and faulting 30

ECONOMIC GEOLOGY
General statement 35
Metals and non-metals 35
Sand and gravels 35
Clay beds 35
Calcareous tufa 36

BIBLIOGRAPHY 37

LIST OF ILLUSTRATIONS

Figure		Page
1	Structural fence diagram of the mapped area	7
2	Erosional column of the stratigraphic section in lower American Fork Canyon.	10
3	View of Mahogany Mountain from the west showing drag folding in the Great Blue limestone.	22
4	Analyses of the structural trends of (a) the major drag folds, (b) the Cattle Creek System of folds, and (c) thrust faults in the mapped area (see Plate 1).	23
5	Analyses of the structural trends of (a) the Timpanogos Cave faults and the Cattle Creek faults, (b) the Burned Canyon reverse faults, and (c) the Wasatch Fault System in the mapped area (see Plate 1).	26
6	Break thrusts on the south wall of American Fork Canyon southeast of the lower power plant.	28
7	Idealized block diagrams showing the structural and physiographic evolution relative to north-central Utah County.	29
8	Drag folded Great Blue limestone truncated by a Wasatch fault.	31
9	Aerial view in vicinity of American Fork Canyon showing ancient erosion surface in background. . .	32
10	Recent Wasatch faults displacing Lake Bonneville sediments on the American Fork delta.	33

Plate		
1	Geologic map and cross sections of the lower American Fork Canyon-Mahogany Mountain area, Utah.	39
2	Index maps.	2

ABSTRACT

An area of approximately 18 square miles between lower American Fork Canyon and Grove Creek Canyon in the south-central Wasatch Mountains was mapped in detail for this thesis. The Timpanogos Cave National Monument is located in the north part of the area.

Sedimentary rocks of the Cambrian, Mississippian and Pennsylvanian systems are well exposed in the mountains and canyons. Lake Bonneville sediments occur in the west part of the area. The Paleozoic rocks are dominantly limestone, although considerable dolomite, shale and orthosiltite are present. The lacustrine deposits are gravel, sand, silt and clay.

Three epochs of diastrophism have disturbed the rocks in the area; these are: mid-Cretaceous, late Cretaceous-early Tertiary, and mid-Tertiary. Thrust faults have displaced rocks eastward. Basin and Range type normal faults, some with displacements of several thousand feet, produced high relief blocks, out of which the Wasatch Range has been sculptured.

Only a few materials in the area are of economic value. Construction materials of gravel, sand, silt and clay are being exploited locally but additional development is remote.

INTRODUCTION

LOCATION

The lower American Fork Canyon area is situated in the northern part of the south-central Wasatch Mountains. It is located two and one-half miles east of the city of American Fork and one and one-half miles northeast of Pleasant Grove (see Plate 2). Mt. Timpanogos, one of the highest and most majestic peaks in the Wasatch Range, is adjacent to the mapped area on the east. The area is bounded by the eastern edge of the Great Basin on the west, by American Fork River on the north and Grove Creek on the south. Most of the area is located in the southwest quarter of the U. S. Geological Survey Timpanogos Cave 7.5 minute topographic quadrangle. Approximately eighteen square miles were studied and mapped.

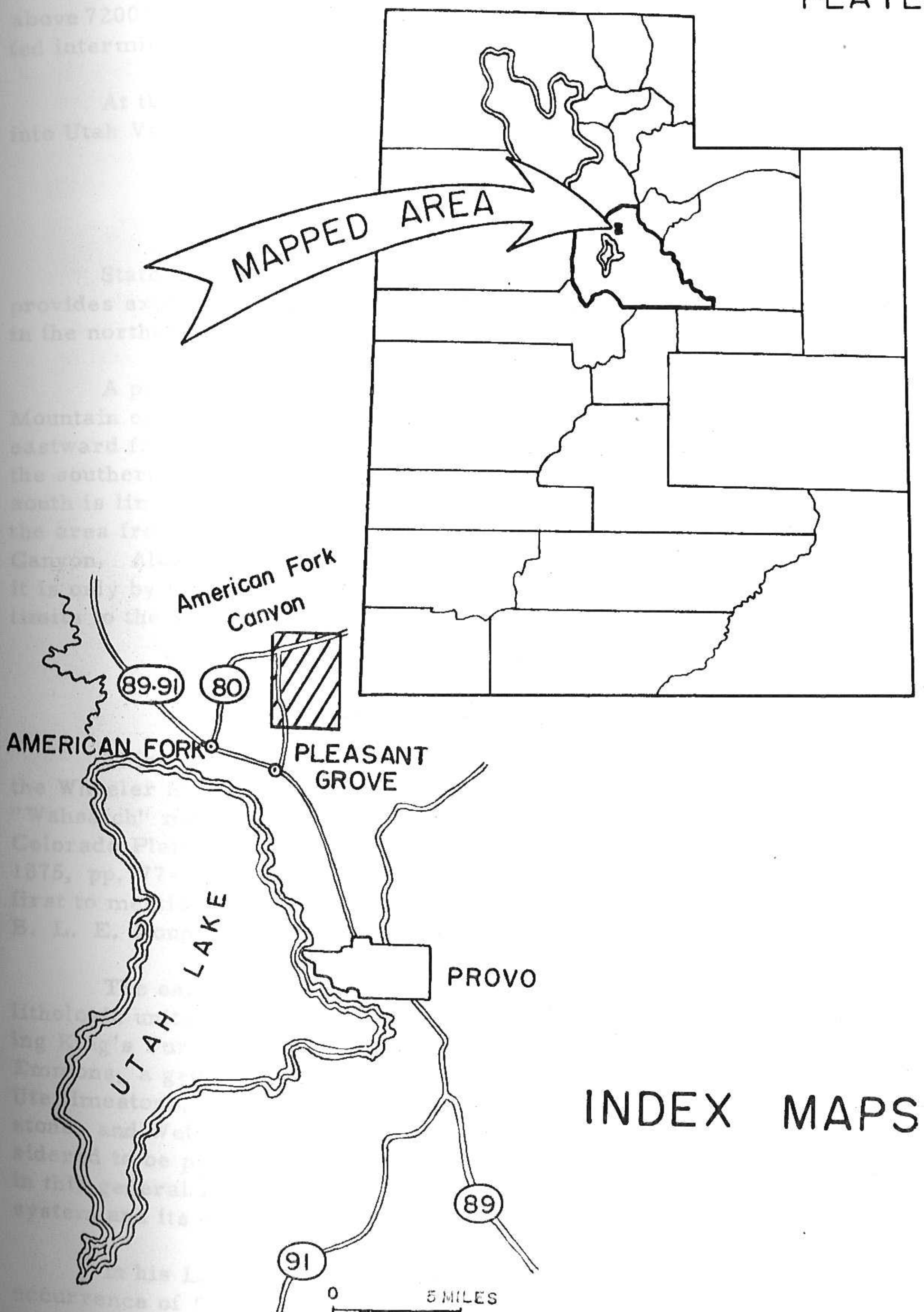
PHYSICAL FEATURES

Topography in the mapped area is generally rugged although some of the upland portion is gently rolling. Mahogany Mountain rises to an elevation of 9000 feet, or approximately 4400 feet above Utah Valley immediately west of the area. A series of cliffs and slopes rises 2900 feet in a lateral distance of one-third mile on the south side of the lower American Fork Canyon. Vertical cliffs in excess of 400 feet high form part of the canyon walls.

The western escarpment of the south-central Wasatch Range is cut by streams flowing westward in steep-walled V-shaped canyons. These rocky canyons illustrate their youthful stage of erosion with interlocking spurs and steep gradients. Very youthful steep gorges extend southward into Mahogany Mountain from American Fork Canyon. Faceted spurs and hanging valleys also characterize parts of the west face of Mahogany Mountain.

The piedmont zone between the Wasatch Range and the Great Basin at the foot of Mahogany Mountain is formed by a group of Quaternary fluviatile and lacustrine deposits and in others as a pediment. Low rounded knolls, now much dissected by streams and faults of very recent origin, contrast to the adjacent bold escarpment to the east.

PLATE 2



INDEX MAPS

Shale strike valleys, on the other hand, which lie at elevations above 7200 feet are broad, shallow features and contain numberous spring-fed intermittent and perennial streams.

At the mouth of American Fork Canyon a mile wide delta is spread into Utah Valley and is dissected by the entrenched American Fork River.

ACCESSIBILITY

State highway 80 traverses the north boundary of the area and also provides excellent accessibility to the Timpanogos Cave National Monument in the northeast portion of the area.

A paved county road which parallels the west flank of Mahogany Mountain extends northward from Pleasant Grove. A horse trail extends eastward from Pleasant Grove through Grove Creek Canyon traversing the southern limit of the mapped area. Accessibility from the east and south is limited to horse trails several miles in length which extend into the area from Provo Canyon and the upper reaches of American Fork Canyon. Although these roads skirt the north and west limits of the area, it is only by foot and horseback that one can penetrate beyond the outside limits to the center.

SUMMARY OF PREVIOUS INVESTIGATIONS

Thirty years after Fremont named the Great Basin, members of the Wheeler Survey confirmed what he had proposed and added that the "Wahsatch" mountains were a perfect natural boundary between the Colorado Plateaus to the east and the Great Basin on the west (Wheeler, 1875, pp. 77-78). G. K. Gilbert, writing in this report (p. 88), was first to mention Lake Bonneville, which he named in honor of Captain B. L. E. Bonneville, an earlier U. S. Army explorer.

The earliest geologic map covering the mapped area, where lithologic units are distinguished, was published in the Atlas accompanying King's Fortieth Parallel Survey Report in 1877 (Map III). S. F. Emmons, a geologist in King's party, proposed the formational names Ute limestone, Ogden quartzite, Sub-Carboniferous, "Wahsatch" limestone, and Weber quartzite which comprise the strata. They are considered to be pre-Cambrian, Silurian, Devonian and Carboniferous ages in this general region. Emmons also discussed the "Wahsatch" fault system and its effect on the topography of Mt. Timpanogos.

In his Lake Bonneville monograph G. K. Gilbert noted the occurrence of Pleistocene lacustrine deposits adjacent to and constituting the western part of the mapped area, and very recent faults which displace them (1890, p. 346).

Loughlin (1913, pp. 439-445) in his report of reconnaissance studies of the Southern Wasatch Mountains, calls attention to the possible tectonic elements responsible for the structure and the distribution of formational units in American Fork Canyon. He also made several age assignments of some formations, utilizing fossils and stratigraphic sequence as evidence.

Geologists compiling the information for Butler's Professional Paper 111 (1920) contributed the first complete geologic map of Utah. On this reconnaissance map rocks of Cambrian and Carboniferous ages are represented in the lower American Fork Canyon area. Paleotectonics in the immediate and adjacent areas were given considerable attention.

G. K. Gilbert (1928) made a detailed study of the Wasatch fault system and the consequent geomorphic developments. During the same year Stillman (1928) reconnoitered the American Fork Canyon area and after a series of plane table traverses was able to advance new postulations dealing with the geologic structure of this area.

Gilluly (1932), through his efforts in the Oquirrh Range, defined the stratigraphy and established type locations for the rocks present in the south-central Wasatch and Oquirrh Mountains which included the Cambrian, Devonian and Carboniferous systems.

Eardley (1933) described the stratigraphy and prepared a reconnaissance map of the southern Wasatch Range while making a correlation of the stratigraphy of the Oquirrh Range and the northern and central Wasatch Range.

A study of the Timpanogos Cave, located in the mapped area, was made by Bullock (1942). He also briefly discussed the general geology of the area.

Calkins and Butler (1943) made an economic study of the mining district northeast of the mapped area and described the stratigraphy and structure which are directly related to the lower American Fork Canyon area. A detailed geologic map of the mining district accompanies their report.

In 1947 A. A. Baker published preliminary stratigraphic data on the south-central Wasatch Range. The Paleozoic units he described are particularly applicable to the lower American Fork Canyon area.

Andrews and Hunt (1948) prepared a geologic map of eastern and southern Utah upon which several faults and the general stratigraphy are noted in the American Fork Canyon area.

The most recent study prior to the writer's investigation was by C. B. Hunt (1953), who studied the Lake Bonneville deposits and related structures adjacent to the Wasatch escarpment in Utah Valley. Much of the Pleistocene history of the area is treated with detail in his work.

FIELD AND LABORATORY STUDIES

The field work upon which this report and accompanying map are based was completed during the summer of 1954.

The use of aerial photographs (scale 1:22, 000) taken in 1946 for the U. S. Geological Survey greatly facilitated the writer in geologic mapping. However, the photographs were valuable only in the mapping of eighty per cent of the area. The northeast portion of the area, in American Fork Canyon, is much too steep for the accurate application of aerial photographs, and thus a topographic quadrangle sheet was employed.

Topographic control was maintained by the use of altimeter and Brunton compass, especially when the topographic quadrangle was utilized. Plane table-alidade control was not necessary.

Following standard techniques of areal geologic mapping the writer adhered to the principles of measurement of sections, lateral tracing of formation boundaries and fault traces and the plotting of the data obtained on a base map. Stratigraphic sections were measured with the aid of altimeter, Brunton compass and steel tape.

Rock samples which appeared to be pertinent to the interpretation of stratigraphy and the processes of sedimentation were collected during the detailed measurement of sections and were studied by microscopic analysis.

GENERAL GEOLOGY

PRINCIPLE FEATURES

The south-central Wasatch Mountains in the vicinity of the lower American Fork Canyon and Mahogany Mountain are composed of Paleozoic sedimentary rocks. Westward in Utah Valley the sediments are Quaternary fluvial and lacustrine deposits; the latter are part of the Bonneville group, while the stream materials are Pleistocene and Recent. The bottoms of stream valleys are veneered with Recent fluvial silts, sands and gravels.

The Paleozoic rocks include representatives of the Cambrian, Mississippian and Pennsylvanian systems. Of these, Cambrian rocks aggregate 1400 feet of quartzite, shale, limestone and dolomite; the Mississippian, 3400 feet thick, is dominantly limestones and calcarenites but subordinate amounts of dolomites, dolarenites and shales are included; undivided Mississippian-Pennsylvanian rocks are 450 ± feet thick, and are composed principally of carbonaceous shales, calcisiltites and orthoquartzites; the Pennsylvanian, more than 17,000 feet thick in adjacent areas, is represented to the east in Mt. Timpanogos, but only its lower beds are considered in this report.

A detailed correlation of these rocks was attempted by Baker (1947) and later by Baker, Huddle, and Kinney (1949). General stratigraphic similarity appears to be shown in the south-central Wasatch Mountains, in the East Tintic Range, the Gold Hill district, the Oquirrh Range, and the Uinta Mountains.

The geologic structure of the lower American Fork Canyon-Mahogany Mountain area is in broad generalities quite similar to contiguous areas in the Wasatch Mountains and conversely very dissimilar in that local portions of it are intensely deformed (see figure 1).

Intricate fold systems characterize the area. The strata have been thrown into broad undulating folds trending north-south. Folding in other systems is open and broad fitting into the regional pattern of an east-west trending synclinorium. Locally the folding is intense. Some general north-south trending folds are directly associated with thrust faulting and are accordingly strongly deformed.

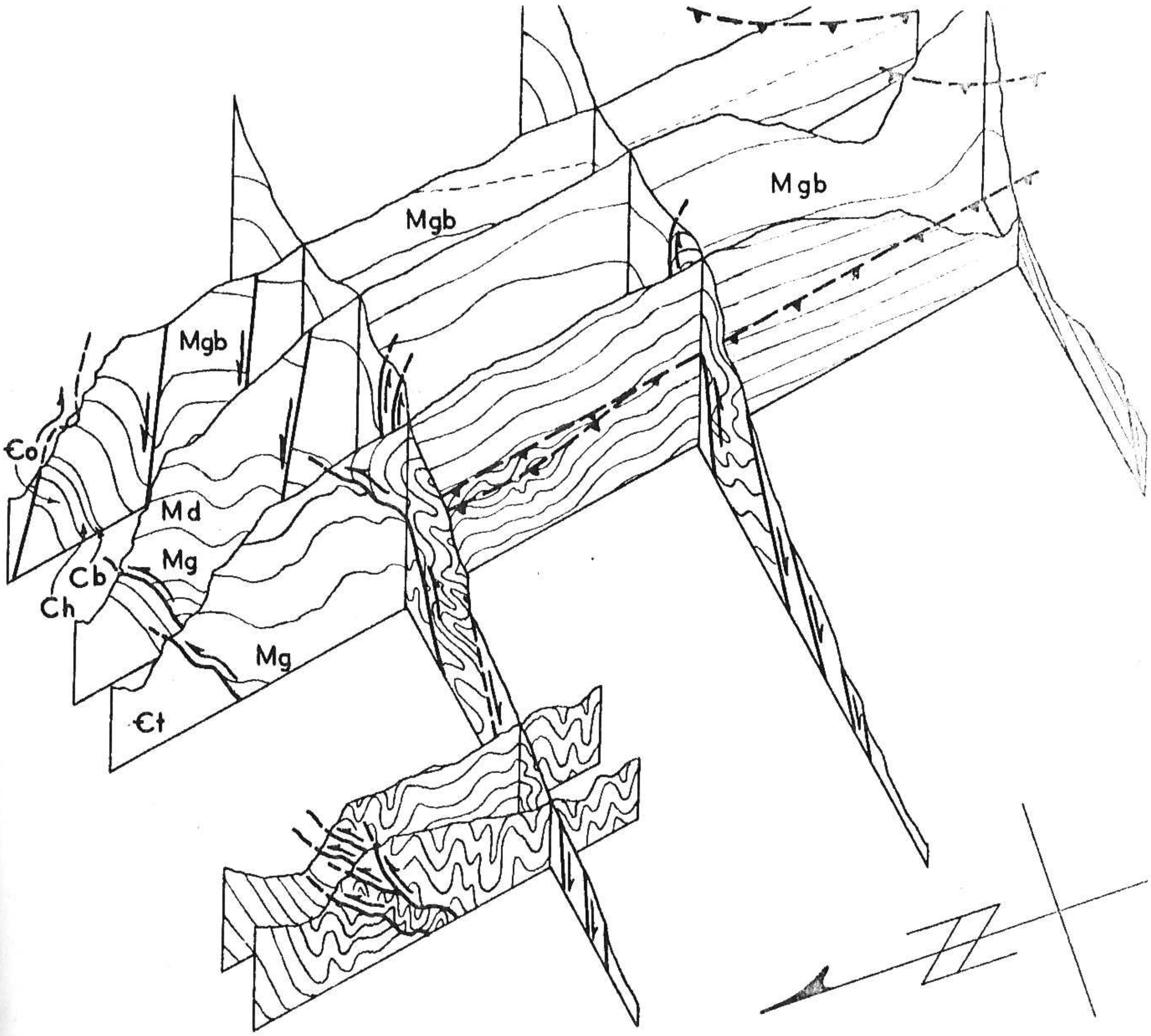


Fig. 1. Structural fence diagram of the mapped area.

Earlier investigators of the general area visualized thrust faults with tens of miles of eastward displacement active in the past, but the writer feels this may not necessarily be a valid concept. Thrust faulting, which is now readily discernible, did occur in Mahogany Mountain and produced a "decken-like" accumulation of rocks, although on a much smaller scale than the term decken implies to some geologists.

A series of en echelon normal faults trends northwest-southeast and borders Mahogany Mountain on the west creating there a huge bold escarpment. The entire length of the mapped area is flanked by this series which is markedly indicated by notable topographic discordance on both sides of the faults, as well as stratigraphic displacement, distinct brecciation and gouge.

Other major faults, some of which are included in a dominantly east-west striking system and show considerable stratigraphic and topographic displacement, occur in American Fork, Burned, and Cattle Creek Canyons. Minor reverse, normal, and tear faults are present throughout parts of the mapped area.

SEDIMENTARY ROCKS

GENERAL SECTION

Sedimentary rocks exposed in the area under consideration have a total stratigraphic thickness in excess of 4800 feet. Included in this section are Cambrian and Carboniferous rocks. Unconformities occur between the top of the middle Cambrian and the Mississippian Kinderhookian strata and also between the Pleistocene Lake Bonneville group and strata of the Carboniferous systems.

Nomenclatoral guides which helped the writer to recognize and trace the stratigraphic units in the mapped area are from Gilluly (1932), Baker (1947), and Baker, Huddle and Kinney (1949). Although these sources deal with stratigraphy specifically outside of the area it was necessary to correlate with them as nearly as possible using paleontologic and lithologic criteria. On the basis of lithologic similarity another name was applied to a Mississippian formation of the area, and on the basis of fossil evidence a formation formerly referred to the Devonian (?) is assigned to the Lower Mississippian.

Figure 2 is a graphic representation and summary of the stratigraphy in the area. The stratigraphy is discussed in the following pages.

Cambrian System

Tintic Quartzite

The Tintic quartzite was named by G. F. Loughlin (1919, p. 25). The type locality is in the Tintic mining district in central Utah. The formation is well developed in the mapped area although the base is not visible there. It outcrops along the lower south wall of the lower American Fork Canyon between Cattle Creek and Burned Canyons where it is a cliff former above steep alluvial cones (see Plate 1).

The formation is principally metaquartzite with a few thin stringers of phyllitic silica shale in the upper part. About mid-way in the formation several thin beds of pebble conglomerate are present. Sericite is common locally in the bedding planes especially toward the top of the formation.

The quartzites generally range from fine to medium grained, from white to dark reddish-brown on fresh fracture, and from cream to reddish-brown (due to hydrous iron oxide) on weathered surfaces. Near the bottom of the exposed section is a bed of purple to maroon phyllitic slate.

Bedding is irregular; thicknesses vary from several inches to many feet. Cross-bedding is widespread showing prominent foreset beds; little constancy of direction is noted. The grains appear sub-angular to rounded although authigenic growth has occured around many grains. Vermiculate-like structures filled with hydrous iron oxide (now much weathered) are very prominent in upper portions of the formation with proximity to the overlying phyllitic shales.

The writer measured 835 feet of this formation. According to Gilluly (1932, pp. 8-9) the Tintic quartzite is Lower Cambrian in age. The writer collected some fossils in the overlying Ophir shale which have been referred to the Lower (?) and Middle Cambrian.

Ophir Formation

The Ophir formation has its type locality within the Ophir mining district on the west flank of the Oquirrh Mountains and was named by Loughlin (1919, p. 25-27). The formation is present as a narrow outcrop band in the lower American Fork Canyon between Cattle Creek and Burned Canyons where it is a slope former. The Tintic quartzite and Ophir formation contact is gradational, being represented by 83 feet of alternating quartzites and silicic phyllites. The bottom of the Ophir formation is considered to be just above the uppermost quartzite stringer.

The formation consists of silicic sericite phyllites and phyllitic slates. Calcareous phyllites occur toward the top near the contact with the overlying Hartmann limestone. The phyllites and slates range from light greenish-gray near the bottom to olive-green and brownish-gray in the middle and top respectively. On weathered surfaces they are predominantly dark olive-green to dark brown. Some pyrite cubes of 1 mm. dimension and occasional 1 cm. nodules of limonite are found in the upper 40 feet.

Vertical slaty cleavage is found prominently developed throughout the extent of the outcrops.

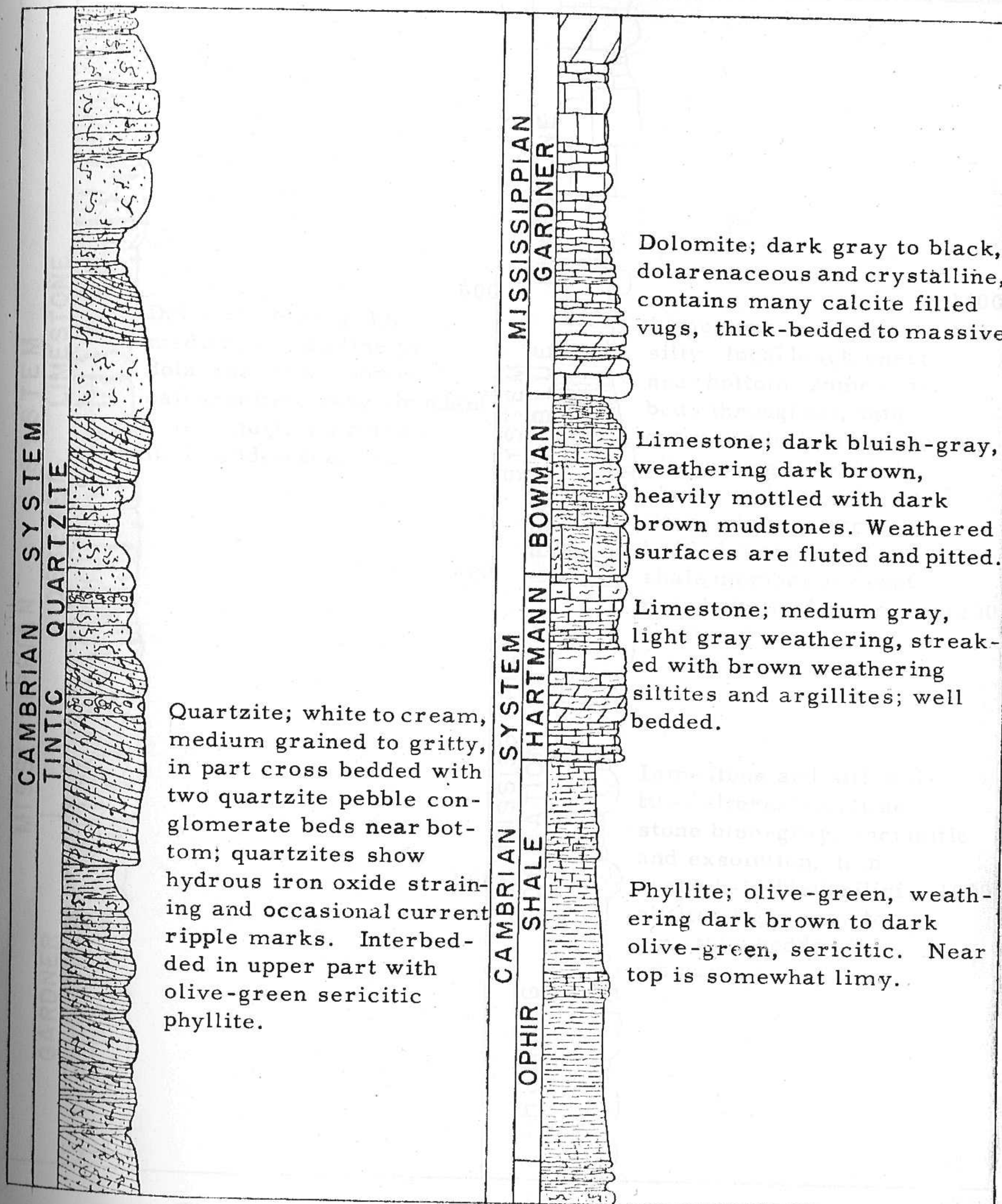


Fig. 2. -Erosional column of the stratigraphic section in lower American Fork Canyon.

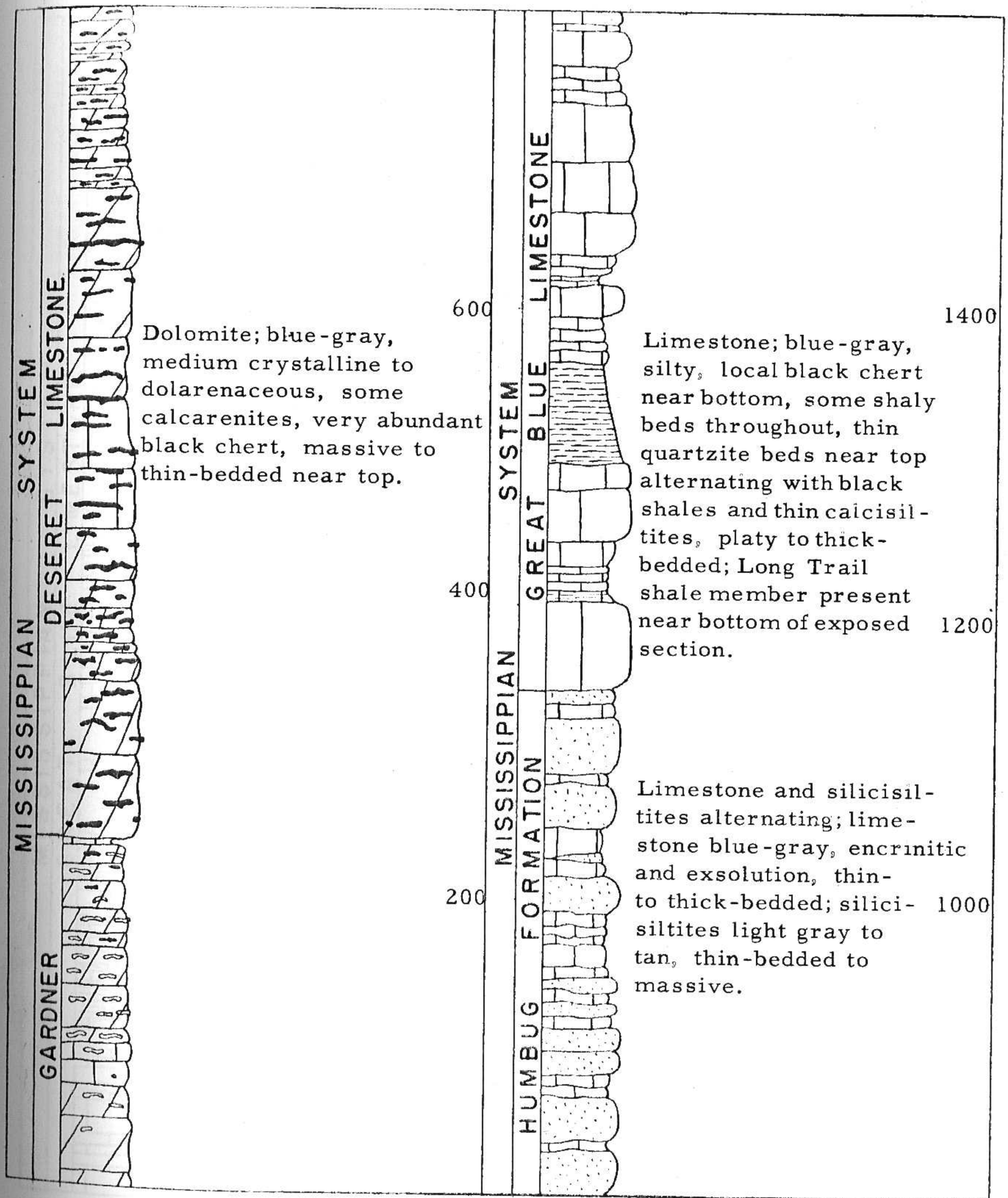


Fig. 2. - (continued)

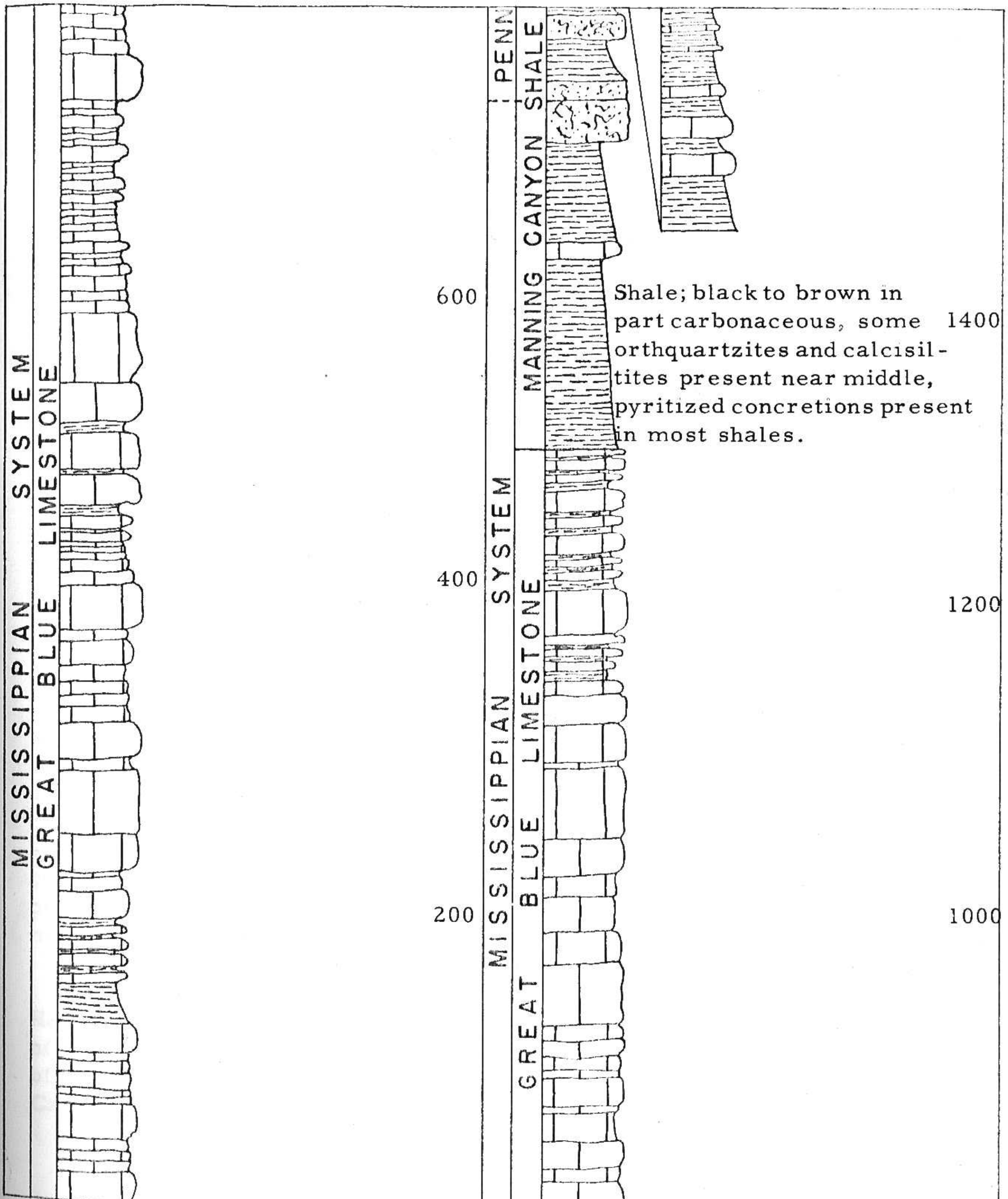


Fig. 2. - (continued)

The writer measured 280 feet of this formation; however, the upper portion is believed to have been cut out or overridden during faulting. In the mapped area the formation varies in thickness from one foot to 350 feet. The normal contact between the Ophir and the overlying Hartmann formations is not present in this area. In other areas this contact is transitional.

Gilluly (1932, pp. 11-12) concluded that the Ophir formation is probably of Middle Cambrian age as determined by stratigraphic sequence and fossil evidence. The writer found what are probably Micromitra sp., Olenellus sp., and Obolus (Westonia) sp. which would indicate at least the upper part of the formation is Middle Cambrian.

Hartmann Limestone

Resting upon the Ophir formation is the Hartmann limestone, named by Gilluly (1932, p. 12) from its occurrence in Hartmann Gulch on the west flank of the Oquirrh Mountains. It appears as a ledge former in the lower American Fork Canyon in a narrow outcrop extending from just east of Cattle Creek Canyon eastward just beyond Burned Canyon.

In the type locality the base of the formation is transitional with the underlying Ophir formation; however, the visible contact in the mapped area is believed to be due to structural adjustments.

The Hartmann formation is composed principally of light gray weathering, medium gray limestone, banded with brown and light gray weathering siltites and argillites in a sinuous streaked manner. The different strata are mottled with varying amounts of the mudstones so that the weathered surfaces have a peculiar indented effect. In some strata the bands of mudstones are parallel to bedding with closely spaced connecting streaks normal to the bedding while in others they are of a pseudoconcretionary nature connected in part with thin streaks of like material.

The writer was unable to locate fossils in the formation, but the Hartmann formation herein is regarded as Middle Cambrian on the basis of stratigraphic sequence and stratigraphic similarity with these and rocks of type locality which Gilluly (1932, pp. 13-14) identified as Middle Cambrian.

Bowman Limestone

The Bowman limestone conformably overlies the Hartmann formation, and outcrops as a narrow brown ledge on the south wall of the lower American Fork Canyon from Cattle Creek Canyon to just east of Burned Canyon. The Bowman limestone was named by Gilluly (1932, pp. 14-15) and occurs in its type locality in Bowman Gulch northeast of Ophir, Utah, on the west flank of the Oquirrh Mountains.

The formation is predominantly a dark blue-gray somewhat argillaceous limestone, heavily mottled with light gray to brown mudstones and dark gray argillaceous limestones and limy argillites. Pyrite nodules 1/4 inch to 3/8 inch in diameter abound in the argillaceous strata. The formation is characterized by its dark-brown weathered surfaces resulting partially from the oxidized pyrite and hydrous iron oxide constituents of the mudstones. The weathered surfaces of most strata display a fluted pitted effect from weathered pyrite nodules leaving small voids and from the less resistant mudstone streaks. Thin bedded strata are light gray weathering and contain many vermiculate calcite filled tubules.

Gilluly (1932, p. 15) determined the age of the Bowman limestone to be upper Middle Cambrian. The only evidences available to the writer for age determination were stratigraphic similarity to the type and stratigraphic sequence.

PRE-LOWER MISSISSIPPIAN UNCONFORMITY

The Mississippian Kinderhookian unconformably overlies the Middle and Upper Cambrian thus representing an interval absent of all Ordovician, Silurian and Devonian rocks. During Ordovician, Silurian and Devonian times the rocks were deposited and eroded away, or this area was mildly positive and no major deposits accumulated.

It is clearly shown in this area that both postulations are in part at least responsible. Angular discordance occurs between the Bowman limestone and the overlying Kinderhookian rocks. The unconformity truncates the bedding in the Bowman limestone progressively eastward.

Mississippian System

Gardner Formation

The Upper and Middle Cambrian strata are unconformably overlain by the Gardner formation. The formation outcrops above the Cambrian rocks from Cattle Creek Canyon eastward for several miles. Throughout its extent in the mapped area it is a high cliff and slight bench former. Wherever the formation outcrops in the south-central and southern Wasatch Mountains and the smaller mountains immediately westward it is made up of a lower and an upper unit.

The lower lithotope consists dominantly of massive dark gray to black dolarenites and light-gray crystalline dolomites interbedded near the top with thick bedded light-gray crystalline dolomites and limestones. The black massive dolomites contain many calcite filled vugs ranging from 1/4 inch to 8 inches in diameter.

The upper unit is dominated by fossiliferous thin-bedded light bluish-gray limestone that is finely crystalline below but increases upwards into more coarsely crystalline material.

Above the thin beds are massive blue-gray limestones and occasional thin beds of crystalline dolomites of the same color all interbedded with brown and black chert in lenses ranging from 1/8 inch to 3 inches thick and up to 4 feet in length. A series of massive, coarsely crystalline limestones above the thin-bedded limestones is overlain by thin-bedded limestone near the top with more abundant chert. A pink weathering, thin-bedded limestone about eight feet thick at the top is continuous throughout the area and is taken as the contact between the Gardner formation and the overlying Deseret formation.

Gilluly (1932, pp. 20-21) thought the lower unit of the formation described above to be middle Devonian age because of stratigraphic similarities to Devonian rocks in the Tintic area and a few poorly preserved fossils. The writer found Triplophyllites sp. and Syringopora sp. in the lower unit as did Rhodes*. Spirifer centronatus, Triployphyllites excavatum, Cliothyridina sp., and Aviculipecten sp. were collected by the writer in the upper unit, indicating the two units are Kinderhookian.

The term Gardner is used in this report instead of Madison because of greater lithologic similarity to the type Gardner dolomite. The term Madison has been used in this section of the Wasatch Range. The lower massive dolomite is overlain immediately by the "curley bed" equivalent, and it in turn by thin-bedded, fossiliferous, in part dolomitic limestone. This sequence is essentially identical to the type Gardner of the Tintic district (Lovering, 1949, pp. 40-52).

Deseret Limestone

The Gardner formation is conformably overlain by the Deseret limestone, the latter named by Gilluly (1932, p. 25). Throughout its exposed extent in the lower American Fork Canyon the formation is exclusively a steep rugged cliff locally cut by minor faults and gorges.

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*Personal communication, May, 1954.

The formation consists of massive blue-gray dolomites and limestones that are medium crystalline to coarse grained dolarenaceous and calcarenaceous. Authigenic dolomitization appears to have been active in replacement of many of the limestones by dolomite. Many beds of calcarenites and crystalline limestones change over to dolomite replaced varieties in a distance of a few yards. . Abundant black chert globules and lenses up to 30 feet in length in the lower portions of the formation and irregularly spaced white calcite filled blebs along with increased quartz arenite content in the upper portion further characterize the outcrops. Because of the increased massiveness of the strata and the marked increase in dolomite and chert content, the formation is distinguished from the underlying Gardner formation.

With the exception of the high dolomite content in the American Fork Canyon area the formation otherwise appears physically correlative with the Deseret limestone formation in the Oquirrh Range by Gilluly (1932, pp. 25-26) and in the south-central Wasatch Range by Baker (1947).

Humbug Formation

The Humbug formation is exposed in the lower American Fork Canyon from one-half mile west of Cattle Creek Canyon eastward beyond Burned Canyon for several miles. It conformably overlies the Deseret limestone and presents a conspicuous banded appearance on the canyon wall. It assumes topographic expression as a series of benches and slopes owing to alternating strata of limestones and calcite cemented silicisiltites and silicarenites.

The formation is composed principally of thin-to thick-bedded blue-gray limestones, in part encrinitic and in part exsolution, and thin-bedded to massive brown and brownish-gray weathering light gray to tan silicisiltites, calcareous orthosiltites and silicarenites.

The limestones and clastic quartz units are generally not traceable over long distances as they locally interfinger and pinch out. The quartzose units are especially lense-shaped. Conditions of deposition of the formation must certainly have included periods of alternating strong turbulence currents to account for the local strong cross-bedded nature of the quartzose units and relative quiet for the exsolution limestones which in some cases immediately overly the quartzose units.

In the mapped area only one three-foot bed of orthoquartzite was encountered in contrast to the dominant occurence of orthoquartzites in the same formation in nearby localities. Livingston* states that in the

*Personal communication, December 4, 1954.

American Fork Canyon area especial conditions existed in the Humbug sea which allowed copius quantities of clastic silt to accumulate; however, only minor amounts of arenaceous material accumulated.

The upper and lower contacts of the formation are arbitrarily drawn because the lensic nature of the quartzose beds makes lateral contact tracing an approximate process. An arbitrary zone in excess of 50 feet thick may not be incorrect for this zone.

Fossils collected from the formation in surrounding areas indicate that it was deposited during Meramecian time.

Great Blue Limestone

J. E. Spurr (1895, p. 375) named the formation from exposures of the "monotonous blue limestone" in the Mercur mining district. The Great Blue limestone formation caps the south rim of the lower American Fork Canyon and covers the entire west slope of Mahogony Mountain. It comprises the main mass of rocks in the mapped area especially in Grove Creek Canyon and the lower one mile of the American Fork Canyon.

The Great Blue limestone conformably overlies the Humbug formation and is gradational with it. The contact is arbitrary but is commonly taken at the top of the highest considerable group of quartzose beds.

The Great Blue limestone is divided into three major parts: a lower and an upper limestone member separated generally by a variable thickness of carbonaceous shaly beds, named the Long Trail shale member by Gilluly (1932, p. 29).

Limestones above and below the black carbonaceous shales are blue-gray weathering light blue-gray and locally contain abundant silt and arenaceous particles. Occasional brown to black chert blebs, subordinate black shale beds, and fine grained lensic quartzites are present. The limestones are platy to thin-bedded making steep slopes frequently and occasionally weathering massive in steep precipitous cliffs.

Because of the "monotonous" thick limestones completely lacking "key" beds and because of its incompetent nature the natural thickness cannot readily be ascertained in an area structurally active in the past. The Long Trail shale would in some areas be a good "key" bed, however in the American Fork Canyon area it was utilized by the structural stresses as a lubricant which subsequently "smeared" it to its now haphazard attitudes throughout its extent in the area.

Age assignments by Gilluly (1932, pp. 30-31) place the Great Blue limestone as Upper Mississippian. More recent studies and correlation agree with Gilluly's assignment and further place it in lower Chesterian. Fossils identified in the field by the writer match collections in other nearby localities which substantiate previous age assignments. The presence of the quartzose-limestone formation below and the thick Manning Canyon shale above serve to stratigraphically locate the Great Blue limestone regionally and in this area.

In Grove Creek Canyon the formation was calculated to be more than 1800 feet thick and in American Fork Canyon the measured section is 1760 feet.

Mississippian and Pennsylvanian Systems

Manning Canyon Shale

Named by Gilluly (1932, p. 31) the Manning Canyon shale conformably and transitionally overlies the Great Blue limestone. It outcrops in Sagebrush Flat and immediately north in shallow strike valleys. The shale is very incompetent allowing the formation of shallow valleys, and owing to its impervious nature numerous springs and abundant vegetation abound. True soil-free outcrops are rare but in stream gorges an occasional exposure is found.

The formation is dominantly black to brown shale in part carbonaceous. Numerous ellipsoidal pyritized concretions are found randomly spaced in the shales.

Associated with the various shale members are platy to thick-bedded light gray weathering medium gray calcisiltites and dark gray to dark brown orthoquartzites.

Fossils obtained from this formation by members of Gilluly's party working in the Oquirrh Range prove to be Upper Mississippian and in part Lower Pennsylvanian. The Manning Canyon shale is a transitional time unit and a time-rock unit. Olsen* and McFarland* found this to be true in adjacent areas for the Manning Canyon shale formation. Likely representatives of the upper Chester and lower Springer occur in this formation.

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*Personal communication, December, 1954.

Quaternary System

Pre-Lake Bonneville Fanglomerate

Pleistocene fans spread apron-like west from the foot of Mahogany Mountain. The fans are indented with wave cut benches of Lake Bonneville and are overlapped by Lake Bonneville deposits thus clearly defining their age as pre-Lake Bonneville.

The fans consist of fanglomerates and are composed of poorly sorted angular limestone boulders, cobbles, and gravels in a silt and sand matrix. Incomplete calcite cementation has proceeded in local areas adjacent to pre-Lake Bonneville and post-Lake Bonneville tufaceous springs.

Lake Bonneville Group

This group of lacustrine sediments was named by Gilbert (1875, p. 89) in honor of Captain B. L. E. Bonneville. It outcrops along the western part of the mapped area and is well exposed in many gullies and gravel pits.

Three formations are represented in the group; they are in order of deposition, the Alpine, Bonneville, and Provo. The lacustrine deposits are principally gravel, sand, silt, and clay, however, some precipitates are present. No differentiation was made for this report.

The Lake Bonneville group is Pleistocene. Vertebrate fossils from the Provo and Alpine formations and stratigraphic position of the group were instrumental in assigning an age to these lake sediments.

Alluvium

The alluvium in the area is a thin veneer of gravel, sand, silt, and clay. It occurs principally in stream gullies and as low cones and fans.

GEOLOGIC STRUCTURE

GENERAL STATEMENT

The area under consideration has been involved structurally in several phases of the Laramide orogeny as well as post-Laramide (?) epeirogeny and major faulting during the Basin and Range epoch. The formation of massive decken-like highly contorted strata associated with numerous major and minor folds and faults, plus the presence of a widespread ancient high level erosion surface and hanging valleys, indicate that this area has been subjected to strong diastrophism.

Several systems of folds and faults are present in the mapped area, all of which contributed to the structural genesis and physiographic evolution. Folds, some showing tremendous distortion, are well displayed throughout the area and reflect the dynamics which have been operative in the past (see figure 1). Normal, reverse, and tear faults are present throughout portions of the area; the normal faults are in well developed systems. Thrust faults present in the area are ramp-like imbricate sheets. Likely they rise upward from the sole of a huge allochthon that extends from a point two miles north of the mapped area for a distance of twenty miles east, and sixty miles to the southeast.

The writer has attempted to correlate, insofar as local evidence permits, tectonic events with those of contiguous areas and with those affecting the region generally.

Folds

Sagebrush Flat Flexure

The Sagebrush Flat structure is a small flexure trending N 10°W, and extending southward beyond Grove Creek and northward into American Fork Canyon. Small anticlines and synclines are superposed upon the flexure, all of which are parallel to and genetically associated with it.

Exposures of the flexure are excellent in American Fork Canyon and at the north end of Sagebrush Flat. Formations from the Cambrian Tintic quartzite to the Mississippian-Pennsylvanian Manning Canyon shale are all gently arched. The fold across its axis is asymmetrical westward where strata of the Deseret limestone formation dip 35° southwest as opposed to more gentle southeast dips of 15° to 20° on the east limb. The flexure conforms to the regional pattern and plunges southward toward the Provo syncline.

Cattle Creek Folds

The Cattle Creek system of anticlines and synclines trends generally east-west; however, individual folds locally trend from N 80°E to N 80°W. See figure 4b for a structural analysis of the folds of this system.

The Cattle Creek syncline is the next largest fold of the system and is designated the type for this discussion (see Plate 1). It trends N 80°E in its eastward extension but swings to the north just west of Cattle Creek where it trends N 80°W, plunges 20° in that direction, and terminates in the cliffs above highway 80.

Rocks of the Great Blue limestone and uppermost strata of the underlying Humbug formation are deformed by this fold. To the east beyond the head of Cattle Creek the syncline has likely been faulted along the axis.

The largest fold of this system is prominently exposed in American Fork Canyon. It is a very large east-west trending anticline which pitches south, is asymmetrical, and west of Cattle Creek is overturned. American Fork River has eroded along or near the axis. Strata of the entire Paleozoic section are involved in the fold, and the strike of these in American Fork Canyon thus far has partially controlled the course of American Fork River. The weakness of the rocks along the axial plane may have been instrumental in directing the river's course.

Other folds of the system are not as large as the two previously described structures, but they are of structural significance. The westernmost of the folds in this system is an anticline which trends N 80°W and plunges a few degrees westward. It has been folded nearly perpendicular to its axis by a fold of a later occurring system. The occurrence of the superposed fold provides evidence by which two deformational epochs may be relatively dated. Several folds of the Cattle Creek system have been displaced a small distance by movements associated with the later thrust faults.

Drag Folds

A system of major drag folds which was developed contemporaneously with the thrust faults is one of the principal structural features of the area. These folds are well exposed immediately north and south of Heisetts Hollow at elevations of 5300 and 5600 feet where they trend N 15°W to N 20°W. Additional folds of the same system are exposed in American Fork Canyon on the south wall three-fourths of a mile east of the mouth. They trend N 30°W to N 55°W. Axial traces of only the major drag folds are shown on the map (see Plate 1). The folds are similar in physical aspect and genesis in all exposures. However, some dissimilarity exists in the magnitude of the folds. Many of the folds are large features amounting to several hundreds of feet in dimension (see figure 3); others are small enough to be collected in hand specimens.

During the thrust fault epoch strata of the Great Blue limestone were folded, overfolded, stretched and finally sheared by continued movement directed from the west. Truncated strata of the folds show thinning and recrystallization of the rocks against the thrust fault planes, phenomena which are characteristic of the drag folds in all exposures.

Not only do the drag folds illustrate the nature of early tectonics operative in the area but they also indicate the direction from which the compressional forces were directed. It is assumed that the compressive

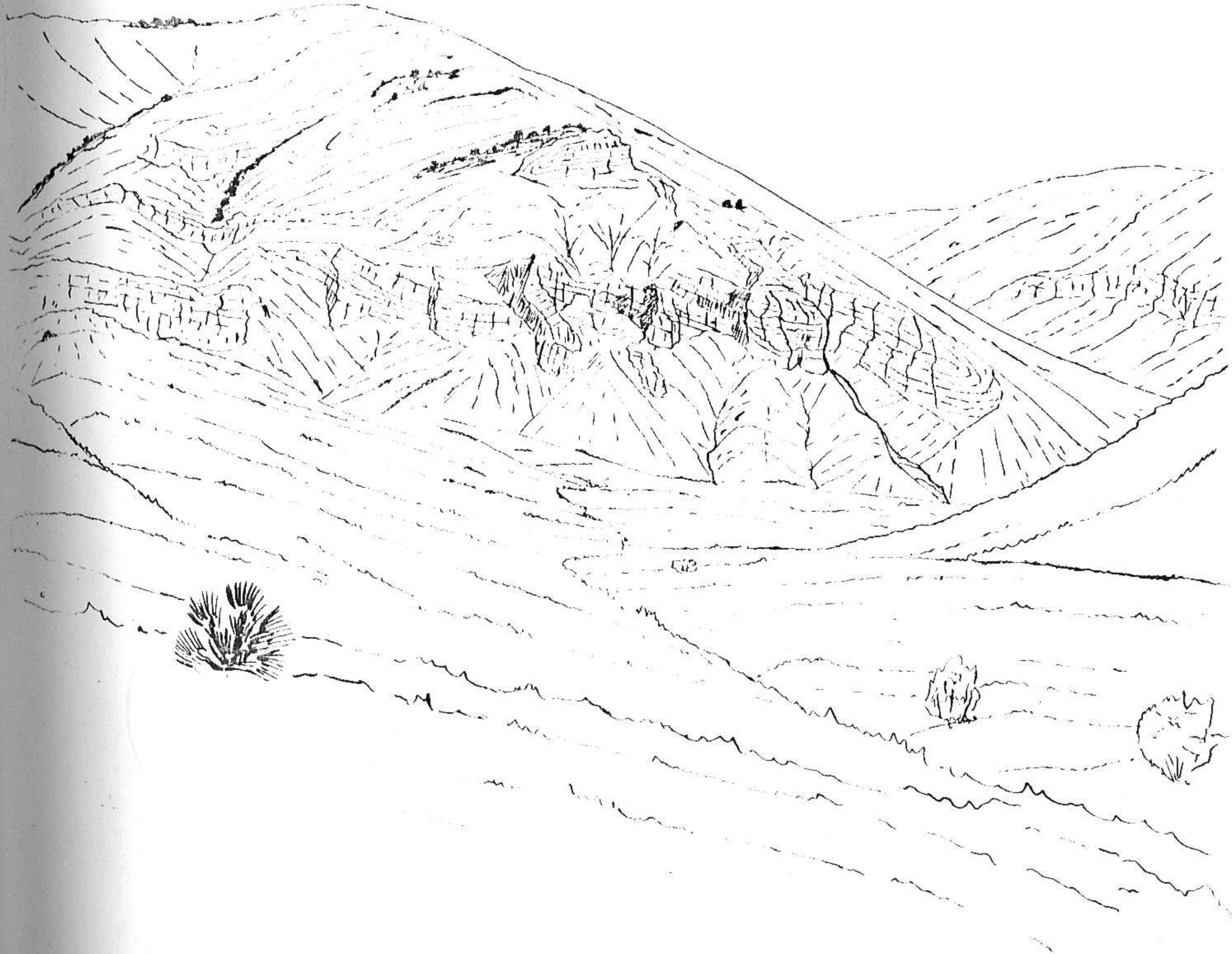

Fig. 3. -View of Mahogany Mountain from the west showing drag folding in the Great Blue limestone. Axes of folds are parallel to plane of paper. Heisetts Hollow in right center background.

forces responsible for an overfold were directed perpendicular to the axis of the fold. The orientation of the drag folds on the map reveals that compressive vectors were directed N. 75°E to N. 70°E in the Heisetts Hollow vicinity and N. 60°E to N. 35°E in the American Fork Canyon vicinity. In effect this supposition is correct, but it is not precisely the key to the varied orientation of the drag folds. The writer proposes that during thrusting the allochthon in moving eastward lost energy against a buttress causing retardation of the northern periphery of the allochthon. This in turn caused the drag folds to swing northwest to their approximate present position. The process is comparable to folds produced by a couple. Proximity of the mapped area to the northern periphery of the great southern Wasatch allochthon supports this postulation. See figure 4a for a structural analysis of this fold system.

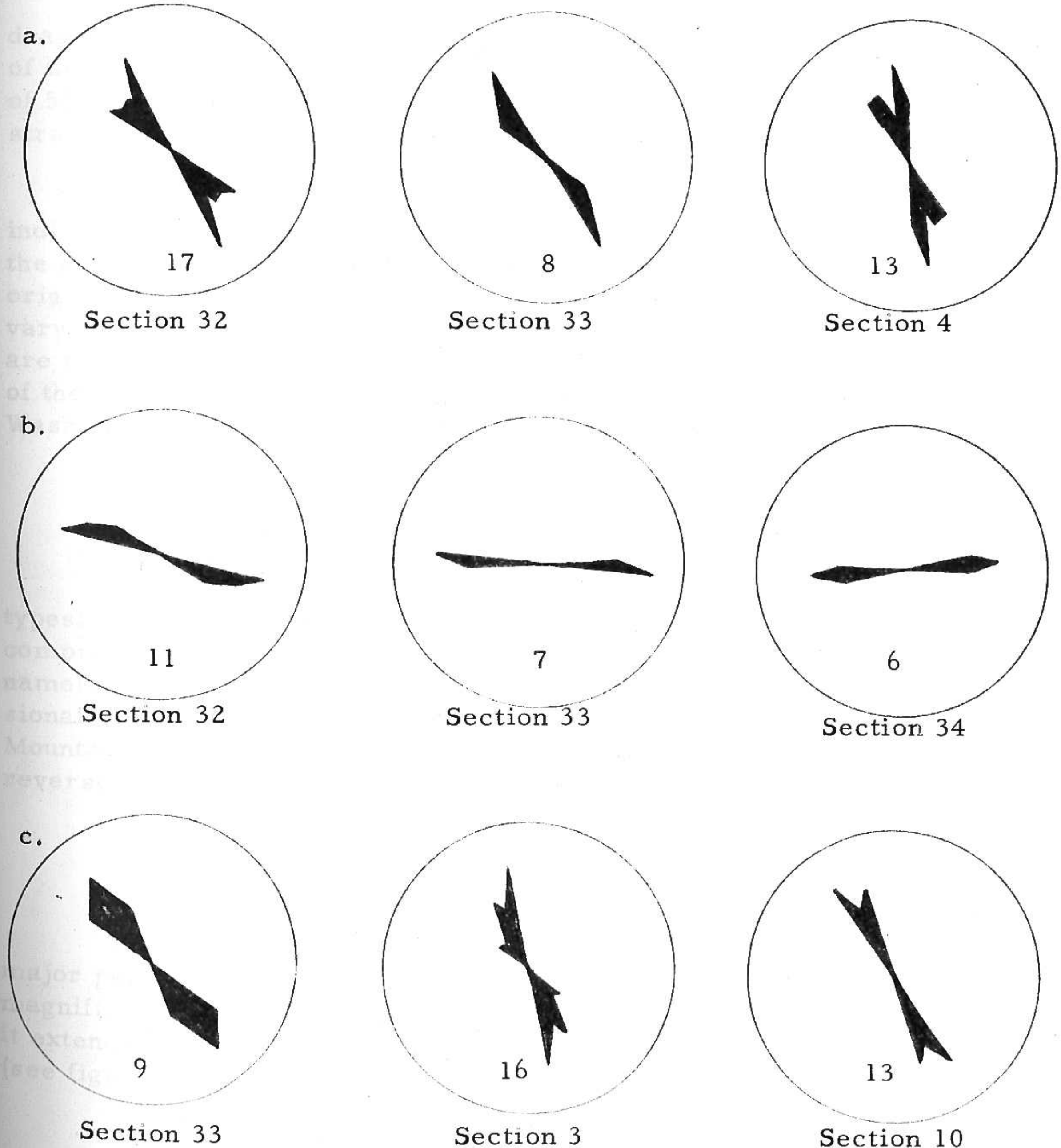

Fig. 4. -Analyses of the structural trends of (a) the major drag folds, (b) the Cattle Creek System of folds, and (c) thrust faults in the mapped area (see Plate 1). The number in each circle indicates the number of determinations utilized.

Grove Creek Anticline

The Grove Creek Anticline trends N 10°W, is recumbent eastward in the vicinity of Heisetts Hollow and asymmetric southward toward Grove Creek Canyon. It plunges 10° toward the south, approximately parallel to the Sagebrush Flat Flexure, and is composed entirely of beds of the Great Blue limestone. On the west the anticline is much broken by the Wasatch Fault System and on the east is adjacent to a shale strike valley.

The Grove Creek anticline part of the drag fold system displays dragging of strata on a grand scale in the central and south-central portions of the mapped area. Strata are dragged under with resultant dips in excess of 55°E. Strata on the western limb dip from 12° to 25° westward. The strata are locally horizontal at the southern end of Mahogany Mountain.

Fracture patterns in the Great Blue strata in Grove Creek Canyon indicate the rocks there were subjected to at least two major stresses in the past. The earlier set are shear cleavages and indicate a compressive origin directed N 85°E. The cleavage traces are filled with calcite and vary from one-sixteenth inch to one-quarter inch wide. The other set are tension fractures (joints) and are indicative of relaxational tendencies of the rocks. The later fractures are nearly parallel to faults of the Wasatch Fault System.

Faults

Faulting in the mapped area is represented by two principal types: those produced by tension (relaxation) and those produced by compression. Two principal systems of tensional faults are represented, namely the Wasatch Fault system and the Cattle Creek system. Compressional faults may also be divided into two general groups: the Mahogany Mountain system of thrust faults, and the Burned Canyon system of reverse faults.

Wasatch Fault System

The Wasatch Fault system likely is responsible in controlling the major part of the physiographic evolution of the mapped area. It is magnificently developed on the west flank of Mahogany Mountain where it extends the entire length of the area and north and south many miles (see figure 1 and Plate 1).

The Wasatch Fault system is a series of normal faults with the hanging wall blocks on the west. The system generally trends N 35°W in the mapped area; however, individual faults locally strike as much as N 80°W. The oldest (and largest) of the faults have displacements measured in thousands of feet and dip at an average of 35 degrees toward the west (see figure 8). In the mapped area they are all dip-slip faults. The Great Blue limestone is at least 1800 feet thick in this area, but due to the Wasatch faults the limestones are repeated over a vertical range of 4200 feet on the west flank of Mahogany Mountain (see figure 7d).

The younger faults are more nearly vertical; in some instances they are between 35°W and vertical. They also have much smaller displacements than the older faults. Most of these displace Pleistocene pre-Lake Bonneville fanglomerates and lacustrine deposits of the Lake Bonneville group. Fanglomerates and lacustrine deposits forming the piedmont zone along the front are involved in a fretwork pattern of these faults. Even in unindurated sediments the escarpments are steep, little vegetated and little eroded. They are obviously much younger than Lake Bonneville and probably are seismically active. See figure 5 for a structural analysis of the faults of the Wasatch Fault System.

Cattle Creek System

Another system of faults which is important in the area is partly responsible for the caves of the Timpanogos Cave National Monument (see Plate 1).

The type for the system is the Cattle Creek fault which trends N.80°E and extends westward across Burned Canyon to the head of Cattle Creek where it grades into the Cattle Creek Syncline. The fault is normal with the hanging wall block dropped on the north. The throw is approximately 700 feet at Burned Canyon where steeply dipping Great Blue limestone strata are juxtaposed on upper Humbug strata.

The Timpanogos Cave Fault strikes N.45°E, dips 75°NW, and near the exit of Timpanogos Cave has a throw of 100 feet. A zone of brecciation and gouge up to 35 feet thick occurs at places along the fault. It is especially evident on the old cave trail 200 feet below the exit of the Timpanogos Cave. Dolomites of the lower Deseret formation are juxtaposed on limestones of the upper Gardner formation along the old cave trail. Most of the breccia and gouge consist of dolomite.

The Timpanogos Cave was formed along the brecciated and gouge zone of the Timpanogos Cave Fault through removal of the highly soluable limestones and dolomites by stream action and solution. Rounded stream abraded pebbles and cobbles are present with clays in the cave which indicates stream activity in the past according to Bullock (1942, p. 42).

The cave, now part of a National Monument, contains many chambers enriched by beautiful stalactites, stalagmites, helictites and other travertine "formation."

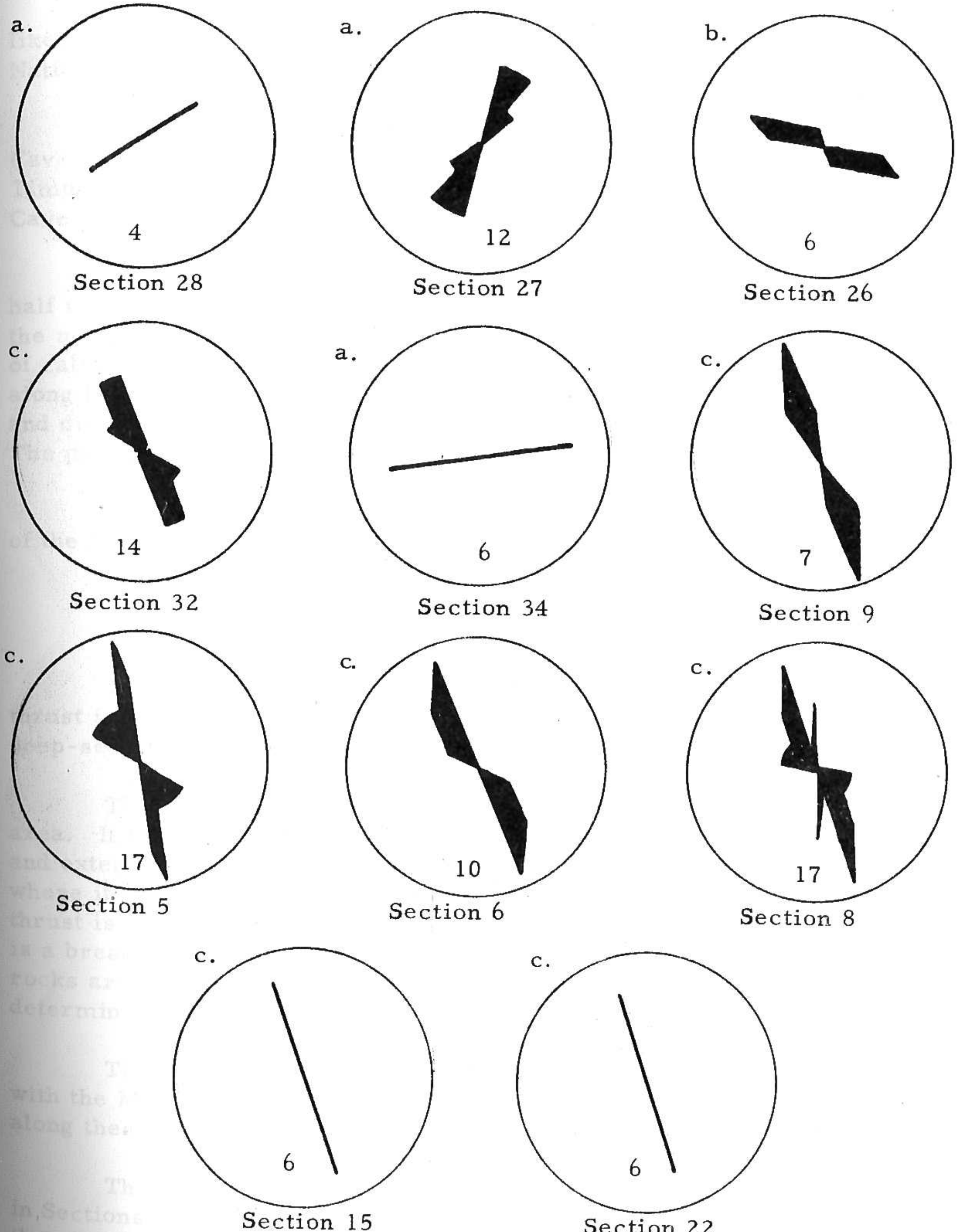

Fig. 5. -Analyses of the structural trends of (a) the Timpanogos Cave faults and the Cattle Creek faults, (b) the Burned Canyon reverse faults, and (c) the Wasatch Fault System in the mapped area (see Plate 1). The number in each circle indicates the number of the determinations utilized.

Other normal faults comparable to the Timpanogos Cave Fault and likely of the same origin are abundant throughout the Timpanogos Cave National Monument. Several of the larger ones are shown on the map.

One of the largest of these faults is the one responsible for the Hansen Cave (considered one of the Timpanogos Cave group). It intersects the Timpanogos Cave fault several hundred feet east of the entrance to Timpanogos Cave and strikes N 40°W.

A large normal fault, downthrown on the north, is inferred one-half mile south of and parallel to the Cattle Creek Fault. It is covered in the mapped area but is presumed to be present due to the displacement of calcisiltites in the Manning Canyon shale formation. The displacement along the fault becomes less toward the west and whether it is rotational and dies out or merges into a subsurface fold is not known to the writer. The postulated trace of the fault is shown on the map (Plate 1).

See figure 5a and Plate 1 for a structural analysis of all the faults of the Cattle Creek System.

Mahogany Mountain Fault System

The Mahogany Mountain Fault system consists of various small thrust faults which are probably imbricate sheets from a much larger deep-seated thrust fault (see figures 1 and 7).

The Mahogany Mountain Fault is the type for the thrusts in this area. It trends N 30° W to N 40°W, dips westward between 60° and 80° and extends from south of Grove Creek to the head of Heisetts Hollow where it probably is not in excess of 100 feet. South of Grove Creek the thrust is considered to be a break thrust by Olsen*. The fault probably is a break thrust a short distance north of Grove Creek; however, the rocks are covered locally and thus the exact nature of the fault was not determined.

Three other small thrusts of this system are arranged en echelon with the Mahogany Mountain Fault and are shown on the map. The displacement along these faults is smaller than along the Mahogany Mountain Fault.

The writer mapped several thrust faults and the Boundary Fault in Sections 32 and 33, Range 2 East, Township 4 South. The trace of the thrust planes in Section 32 is east-west, but actually they strike generally north-south. The thrusts are generally horizontal and to the east they rise in ramp-like fashion. The rocks were deformed during and after formation of these thrusts and hence have contorted the thrust planes making it practically impossible to map them. These thrusts are intimately associated with

*Personal communication, December 20, 1954.

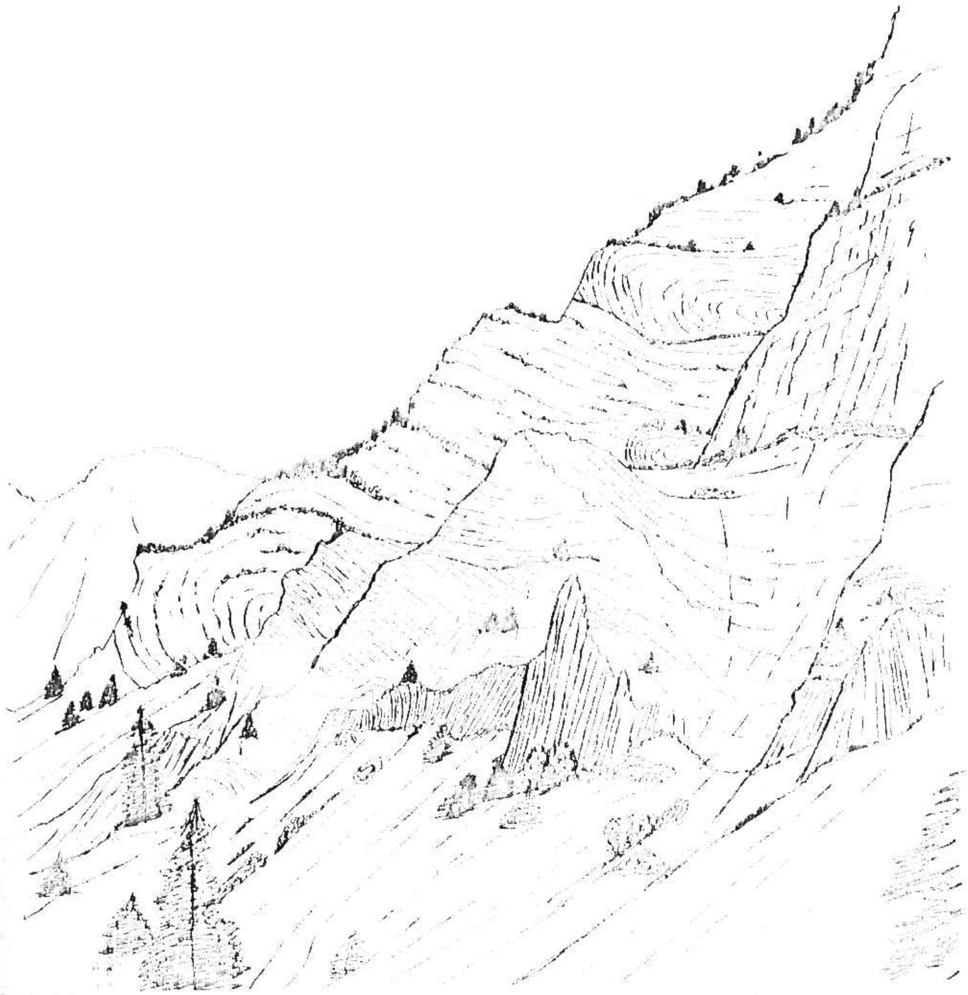

Fig. 6. -Break thrusts on the south wall of American Fork Canyon southeast of the lower power plant.

well exposed drag folds in the Great Blue limestone. Break thrusts are common throughout Section 32, Township 4 South, Range 2 East (see figure 6).

The Boundary Fault is a very high angle thrust which stikes approximately N10°W and dips westward about 80°. It would be confused with a normal fault in that Great Blue limestone strata are juxtaposed on older Humbug and Deseret strata except for the drag folds in the Great Blue strata. The drag folds along the fault indicate the Great Blue beds were moved eastward in ramp-like manner over the older Mississippian formations. See figure 4c for a structural analysis of these faults.

Burned Canyon Reverse Fault System

The Burned Canyon Fault system extends from Burned Canyon westward into the Timpanogos Cave National Monument (see Plate 1) and in all probability to the west as far as the surface extension of the Ophir shale.

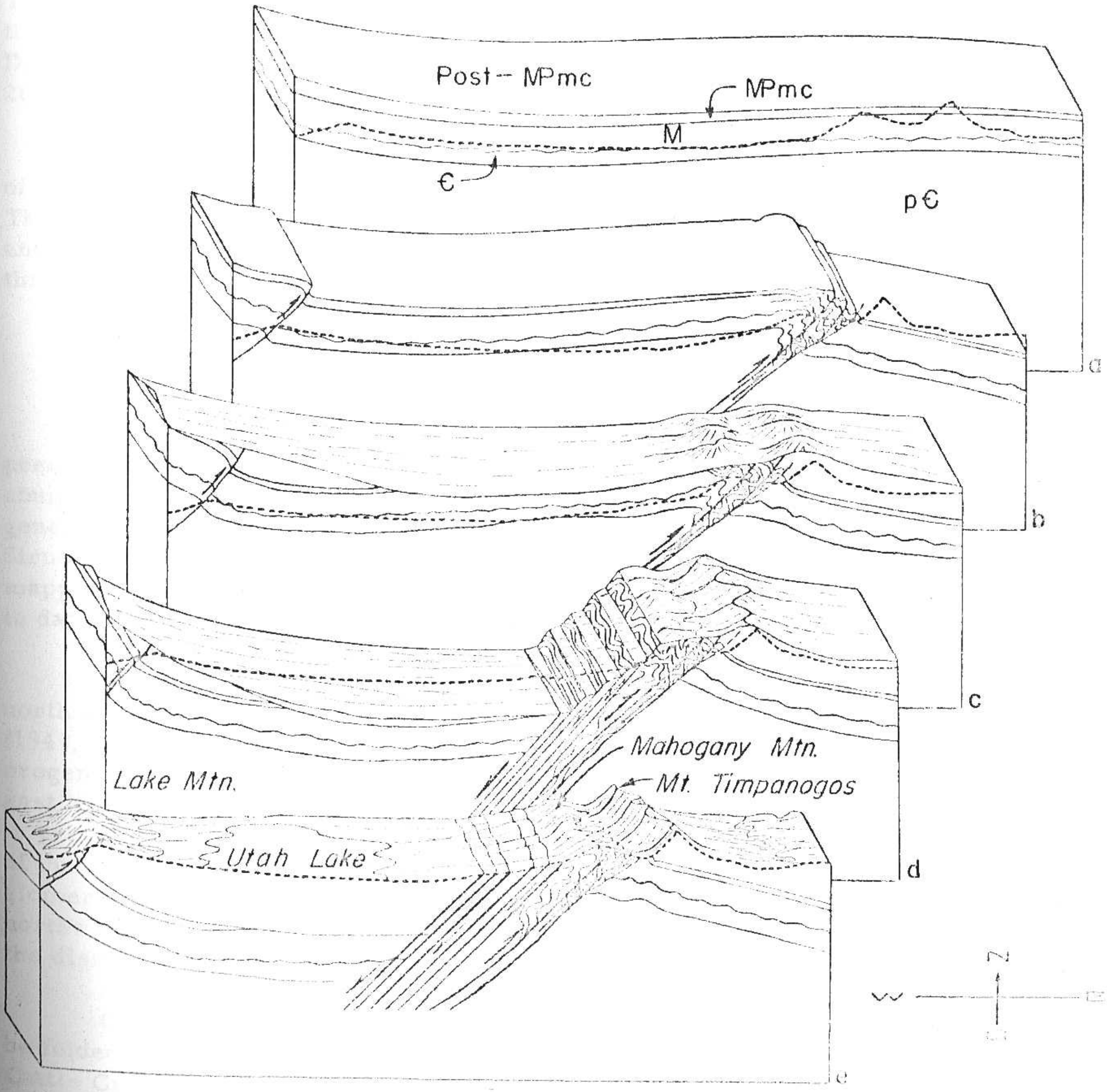

Fig. 7. - Idealized block diagrams showing the structural and physiographic evolution relative to north-central Utah County. (a) pre-Laramide; (b) second stage of early Laramide; (c) post Laramide erosion to sub-mature topography; (d) Basin and Range Epoch-Wasatch Fault System; (e) erosion and valley filling to present.

On the west wall of Burned Canyon, especially near the mouth, there are several small dip slip reverse faults. The most prominent of the faults has brought the Tintic quartzite up against the Ophir shale. The fault stikes east-west and dips 85°N to vertical. The fault is also visible in the high cliffs immediately southwest of the mouth of Burned Canyon. A remnant of the up-thrown block remains as a horse against the cliffs after erosion has stripped away a great portion of the block. The remnant is composed of Gardner and lowermost Deseret rocks up-thrown in one block onto uppermost Gardner strata and rocks of the middle Deseret formation. The displacement along the fault is approximately 200 feet. A thick breccia zone is present at the west end of the block.

Small reverse faults arranged en echelon south of the main fault of this system have displacements commonly measured in tens of feet. These faults occur in the Ophir shale on the west side of Burned Canyon and in the Cambrian carbonates on the east side of the canyon with the up-thrown block on the north.

Date of Folding and Faulting

No direct evidence is present in the mapped area by which one can precisely date the various folding and faulting epics. However, there are abundant data available in adjacent areas and in the central Utah region generally which attest to the diastrophism which has deformed them. Structural trends in this broad area and the phenomena observed in the mapped area direct the writer to relate many of the structural trends here to data collected by other investigators in the surrounding areas.

Thick conglomeratic deposits of early Late Cretaceous age occur north and south of this area for distances of several tens of miles. Eardley (1949, pp. 10-23) considers them to be the result of a middle Cretaceous orogeny. He named the orogeny after the Cedar Hills, a group of low hills east of the southern Wasatch Range, where 15,000 feet of the coarse deposit is present. Strong uplift to thrusting are believed to have occurred just west of the present Wasatch Range immediately preceeding deposition of the conglomerates. As the belt of orogeny likely extended from southern Nevada northward into Wyoming it is highly probable that this area was affected by the distrubance; however, no direct evidence is discernible.

Genesis of the Cottonwood uplift caused the Paleozoic sediments to be folded in an east-west-trending system represented in this area by the Cattle Creek system of folds. Eardley (1951, p. 328) believes this disturbance to be the first stage of the early Laramide orogeny. During this folding the fault paralleling the axial plane of the large east west fold in American Fork Canyon was developed.

The Sagebrush Flat Flexure is related to the north-south trending folds reported by Spieker (1946, pp. 152-155) to have been formed during a period of intense east-west compression between middle and late Montana time. Thrusting on a large scale is believed by Spieker to have occurred with or late in the epic of folding. Eardley (1951, pp. 328-330) terms this epic as the second stage of the early Laramide orogeny and confirms the occurrence of large thrusts during this time.

Imbricate sheets from the large thrust which is responsible for the building of the south-central and southern Wasatch Mountains caused the incompetent upper Mississippian strata to be intensely deformed during movement along the thrust planes. The major drag folds now visible in the area were formed during the latter part of the second stage of the early Laramide orogeny (see figure 7).

The westernmost anticline of the Cattle Creek system is folded transverse to its strike by one of the overturned drag folds related to this thrust faulting (see Plate 1), and therefore relatively dates the fold systems.

The Grove Creek Anticline was formed during this paroxysm and the Sagebrush Flat Flexure was further arched as is evidenced by the eastward rotation of the Cave Trail thrust plane. Blackwelder (1925, pp. 132-133) cites the occurrence of east rotated thrust planes from farther north near Logan, Utah, and of the same approximate age.

Fig. 8. - Drag folded Great Blue limestone truncated by a Wasatch Fault. Gently west dipping Great Blue strata above the fault. View looking south at mouth of Heisetts Hollow.

From the evidence available it may be concluded that the north-south folds and the thrusts were at least in part penecontemporaneous and likely occurred in the Montana phase of the Laramide orogeny; in general they fit into the regional pattern.

The next orogeny which affected the mapped area and those contiguous is perhaps best termed the late Laramide orogeny and is thought by Spieker (1949, pp. 78-80) and Eardley (1949, pp. 21-22) to have occurred in middle or late Eocene time. Regional north-south folding occurred which Eardley (1949, p. 30) believes is responsible for the modern ranges

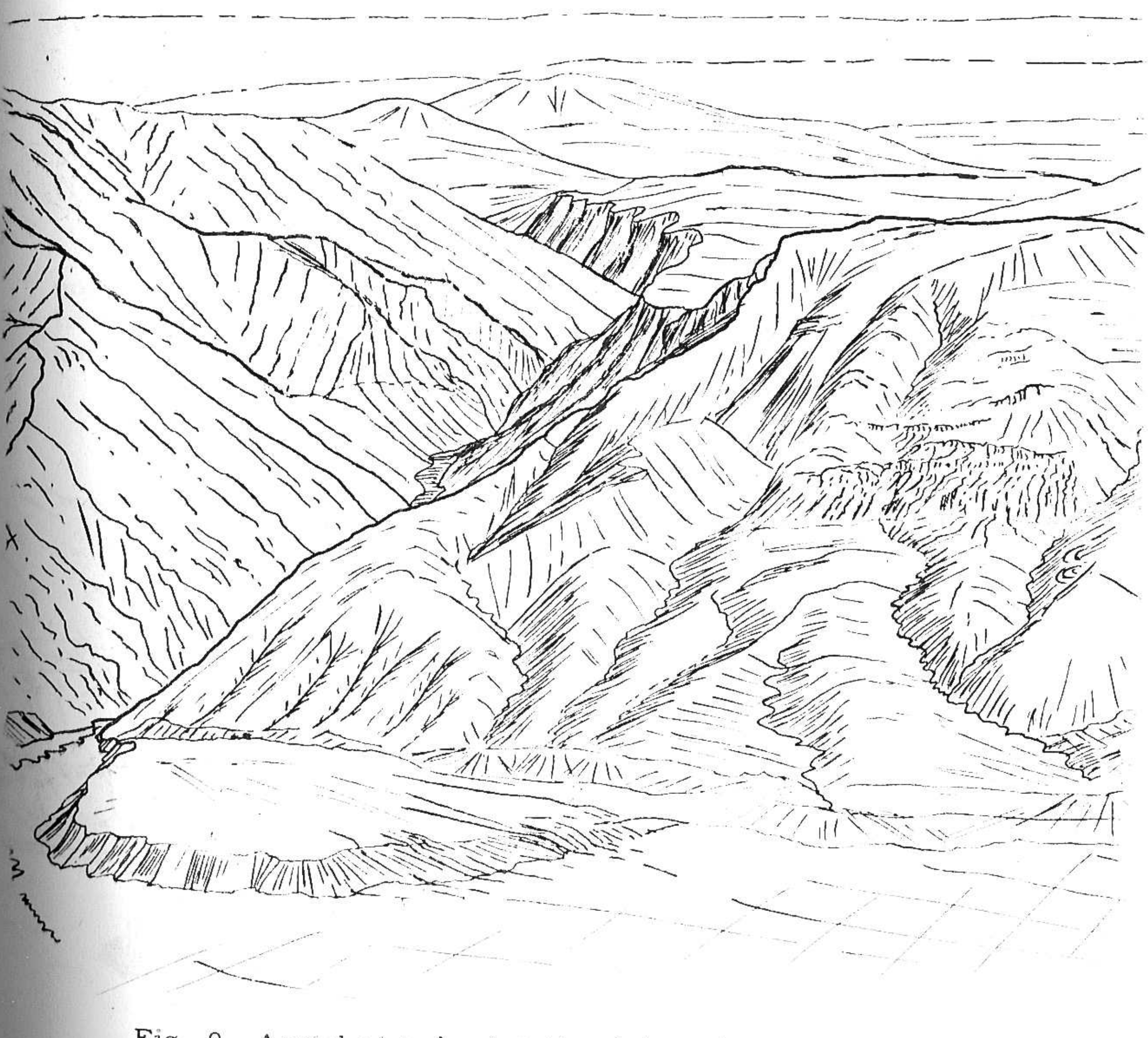

Fig. 9. -Aerial view in vicinity of American Fork Canyon showing ancient erosion surface in background; Mahogany Mountain, and the Lake Bonneville delta at the mouth of American Fork Canyon in foreground.

of the Great Basin. An early uplift of the east-west trending Uinta Mountains accompanied by development of great east-west trending anticlines and synclines in the Wasatch Range during this epoch caused the Sagebrush Flat Flexure and the Grove Creek Anticline to plunge southward toward the Provo Syncline at the south end of Mt. Timpanogos.

Prior to the Basin and Range epoch of faulting partial peneplanation of the south central Wasatch Range occurred (see figure 7c) and in this area a remnant of the peneplane still exists in the vicinity of American Fork Canyon (see figure 9). A mature topography that developed there and in Sagebrush Flat is still in evidence. A poorly drained valley system once existed as evidenced by local stream gravels on the flats in upper American Fork Canyon. American Fork Canyon is simply a huge gorge cut into the old erosion surface.

Grove Creek has a low gradient in Sagebrush Flat; but as it approaches the frontal escarpment it develops into a steeply graded swift stream and has cut a deep gorge into Mahogany Mountain. Eardley (1939, pp. 243-267) refers to others like this as "hanging valleys."

Immediately following the Absarokan orogeny which affected the northern part of Utah in Oligocene time, but doubtfully this area, and with little or no great time interval, Basin and Range faulting commenced. In northern Utah the Norwood tuff of Oligocene age is cut by these faults. A

Fig. 10. Recent Wasatch faults displacing Lake Bonneville sediments on the American Fork delta.

well developed system of normal faults occurred intermittantly during late Eocene and Oligocene time and is perhaps continuing even now along the west flank of Mahogany Mountain and in other areas (see figure 7d). Some of the smaller nearly vertical faults may have occurred in the last several hundred years or less (see figure 10).

The normal faults in the vicinity of the Timpanogos Cave National Monument are believed by the writer to be approximately the same age as the normal faults on the west flank of Mahogany Mountain. According to Bullock (1942, p. 36) recent movement along the Timpanogos Cave Fault has broken stalactites and lowered the ceiling a few inches.

ECONOMIC GEOLOGY

GENERAL STATEMENT

The economic value of the area under consideration can be placed conveniently into two categories, (a) tourist attraction and (b) mineral possibilities.

The Timpanogos Cave National Monument, operated and maintained by the Department of the Interior, National Park Service, affords scenic beauty to many thousands of tourists annually. A group of caves bearing the monument name is located in the monument. The Timpanogos Cave group is a series of three tunnel-connected caves open to the public, plus several other chambers not open currently.

METALS AND NON-METALS

Three prospect adits are located in the mapped area. To the writer's knowledge none have produced on a commercial scale. The two metalliferous prospects are just west of Cattle Creek near State Highway 80; they occur along a thrust fault. The adits were probably excavated to investigate the iron oxide stains in the brecciated limestone. The third prospect is on the west side of Mahogany Mountain south of Heissets Hollow. The site was claimed in 1953 for the purpose of extracting gypsum from an enriched zone at the intersection of several faults of the Wasatch system. A very small dump indicated little effort was expended to operate the claim. In all probability the gypsum has been deposited by ground water after being taken into solution in the gypsifferous Manning Canyon shale located above the faults.

Sand and Gravel

Sediments of the Lake Bonneville group have been exploited along the west flank of the area studied for this report and in the delta at the mouth of American Fork Canyon. The sand and gravel from these localities are reported to be of high quality.

Clay Beds

Some clay is taken from a few pits in the Manning Canyon shale northeast of Pleasant Grove in the foothills along Mahogany Mountain. The pits are small and contain low quality clay. Operation of these pits is intermittent.

Calcareous Tufa

A two-acre accumulation of calcareous tufa is associated with small outcrops of Manning Canyon shale in the foothills along Mahogany Mountain. Early residents of the area used the tufa for building stone. The method of mining was with a hand axe as the rock can be easily hewn when wet.

The tufa is adjacent to a small fault of the Wasatch system. The deposit was likely precipitated from water issuing from a spring developed along the fault.

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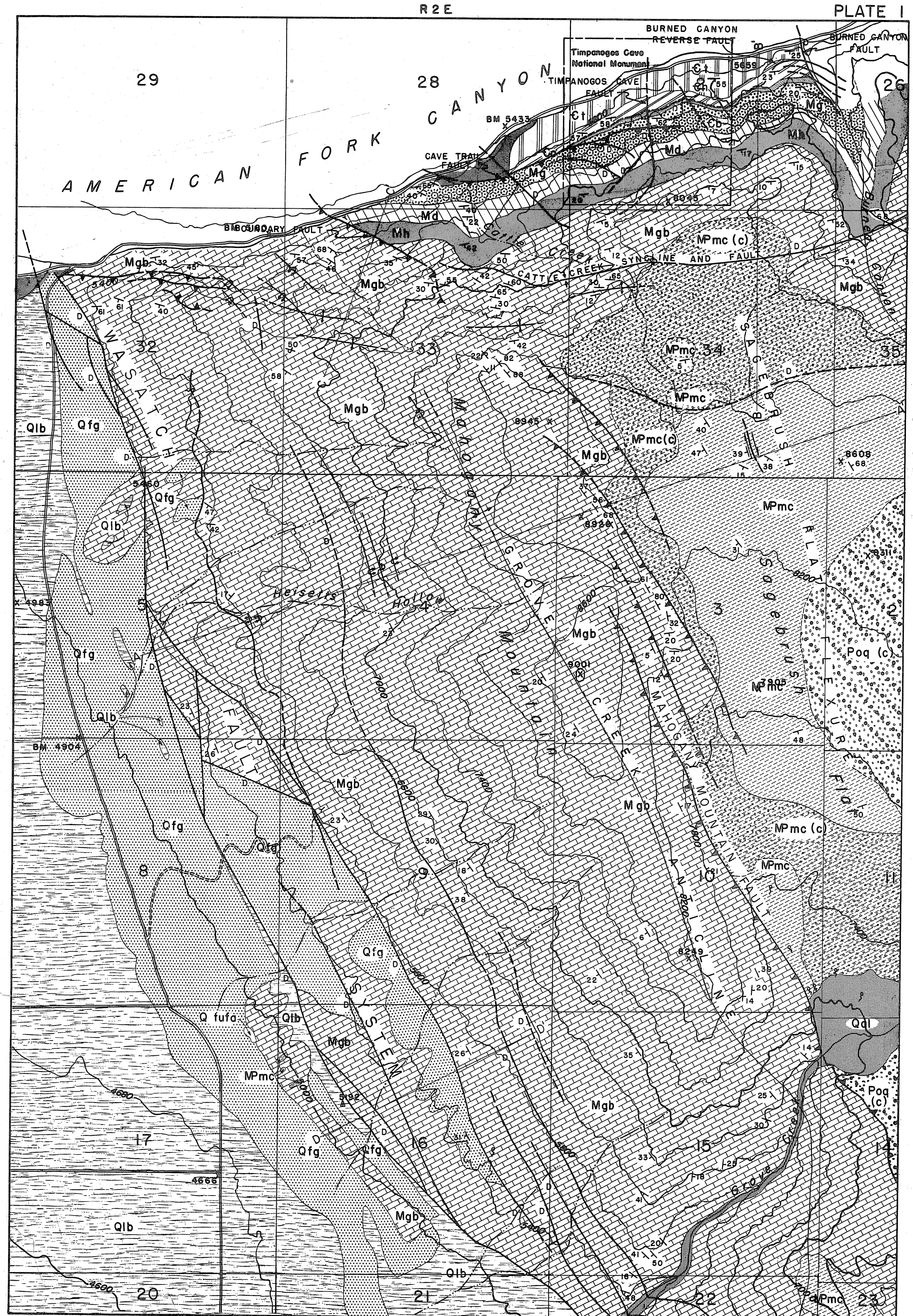
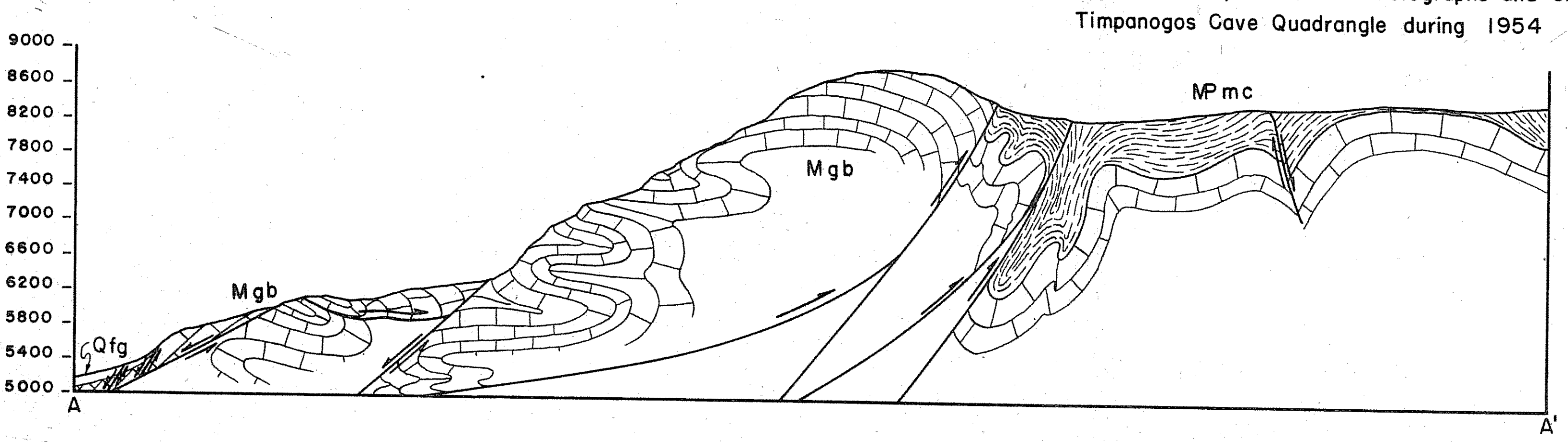
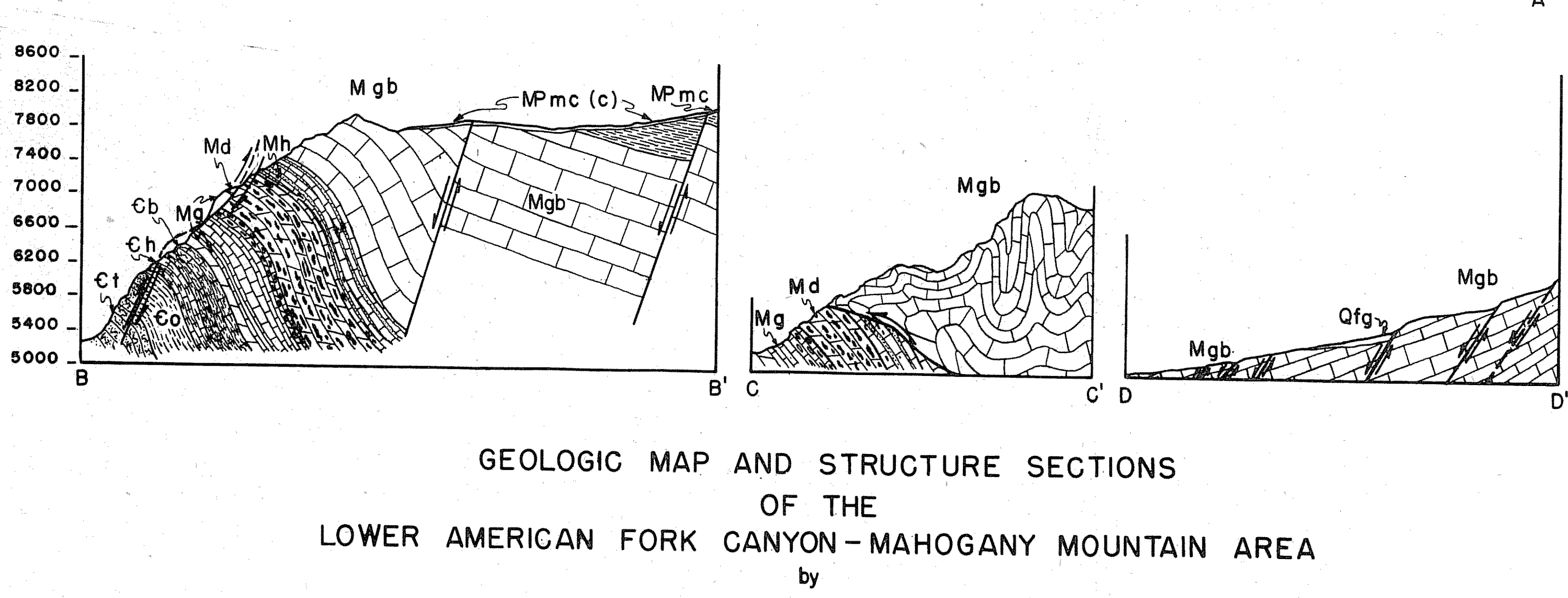
PLATE I



Base map enlarged from U.S.G.S. Timpanogos Cave Quadrangle

Mapped on 1:22,000 Aerial Photographs and U.S.G.S. Timpanogos Cave Quadrangle during 1954





EXPLANATION

SEDIMENTARY ROCKS

QUATERNARY

- Qal — Alluvium
- Covered with designated material
- Qlb — Lake Bonneville group
- Qfg — Fan gravel

UNCONFORMITY

PENNSYLVANIAN

- Poq — Oquirrh formation

PENNSYLVANIAN – MISSISSIPPIAN

- MPmc — Manning Canyon shale

MISSISSIPPIAN

- Mgb — Great Blue limestone
- Mh — Humbug formation
- Md — Deseret limestone
- Mg — Gardner dolomite

UNCONFORMITY

CAMBRIAN

- Cb — Bowman limestone
- Ch — Hartmann limestone
- Co — Ophir shale
- Ct — Tintic quartzite

SYMBOLS

- Strike and dip
- Strike and dip of overturned strata
- Fault — showing probable location where dashed
- Fault — showing relative movement
- Thrust fault (teeth on overthrust block)
- Anticline — showing trace of axial plane
- Syncline — showing trace of axial plane
- Anticline — overturned
- Syncline — overturned
- Unimproved road and trail
- Paved road
- Adit
- Quarry
- Streams
- Intermittent stream

True North / Magnetic North 16½°

SCALE 1:24000

0 — 1 MILE

CONTOUR INTERVAL 400 FEET

GEOLOGIC MAP AND STRUCTURE SECTIONS OF THE LOWER AMERICAN FORK CANYON – MAHOGANY MOUNTAIN AREA

by

RICHARD F. PERKINS

1955