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Preliminary reconnaissance study of Lower  
and lower Upper Mississippian strata across  
northwestern Utah

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This report is preliminary and has not been  
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PRELIMINARY RECONNAISSANCE STUDY OF LOWER AND LOWER UPPER MISSISSIPPIAN  
STRATA ACROSS NORTHWESTERN UTAH

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INTRODUCTION

Purpose and scope

This study was planned to examine, sample, and evaluate biostratigraphically important Mississippian sections across the northwestern quadrant of Utah in the northeastern part of the Basin and Range Province. It is part of the U.S. Geological Survey project on the petroleum geology of Paleozoic rocks of the Cordilleran miogeosyncline, under the direction of Charles A. Sandberg, project chief, Denver, Colorado. Field work was conducted during seven weeks of June, July, and August 1975. Twenty-three sections were examined in ten mountain ranges. (See locality register, p. 4-7.) The magnitude of the task in terms of thickness and volume of sedimentary rocks deposited during Mississippian time (fig. 1A) mandated a largely reconnaissance study. Nevertheless, the voluminous literature describing these rocks permitted some important conclusions to be made with a minimum of new data.

The objectives of the study are as follows:

1. Reconnaissance examination of many of the best exposed previously described Mississippian sections in northwestern Utah, and detailed measurement and description of critical parts of these sections.
2. Collection of rock and fossil samples to provide more precise time-rock correlation of units from sections in the Great Basin to those in the Rocky Mountains. Samples are to be used for conodont acid-extraction, organic-carbon analysis, phosphate spectrographic analysis, lithologic and thin-section description, and megafossil determination.

3. Evaluation of the geological history of these rocks in terms of current interpretations and subsequent field and laboratory observations and determinations in the context of the economic petroleum and mineral resources potential.

#### Previous work

This stratigraphic problem is related to the sedimentational-structural framework and crustal shortening between the Middle Rocky Mountains and Basin and Range Provinces. Geologists have noted some disparity between Mississippian sections east of the Bear River and Wasatch Ranges and those within and west of these ranges (Crittenden, 1959). This disparity is reflected by facies gradations and thickness changes, with thicker sequences to the west and thinner sequences to the east (fig. 1A). Consequently, there are numerous changes in stratigraphic nomenclature across northern Utah (fig. 1B).

A major stratigraphic break represented by an extensive unconformity between Osagean and Meramecian rocks was recognized and proposed by Laudon (1948) for interior cratonic and Cordilleran sections. More recent studies that give additional evidence for this conclusion include those of Sando, Dutro, and Gere (1959), Dutro and Sando (1963), Sando and Mamet (1974), Sando and Dutro (1974), and Sando (1975). The Mississippian history of the northern Cordilleran region of the United States, outlined by Sando (1974), is shown diagrammatically by figure 2. It should be noted that Sando established the unconformity within the Meramecian but before middle Meramecian time. Based on fossils obtained from rocks deposited on the cratonic platform, a megafaunal and microfaunal zonation for the Mississippian was established by Sando, Mamet, and Dutro (1969). The zonation was based primarily on three fossil groups--corals, brachiopods, and Foraminifera--with emphasis on the calcareous Foraminifera because of their phylogenetic diversity and cosmopolitan distribution (Mamet and Skipp, 1970).

Surprisingly, conodonts which are so useful for worldwide zonal correlations, were not utilized in the zonation of Sando, Mamet, and Dutro (1969). There have been serious problems with critically reconciling the foraminiferal and conodont zonations for late Osagean rocks (Brenckle and others, 1974). At the crux of the problem in the western United States is the time-rock correlation of Osagean strata from the cratonic platform in the Middle Rocky Mountains across the Basin and Range Province of northern Utah.

The sedimentary framework for Mississippian deposition across northern Utah in the context of a plate tectonics model was graphically outlined and documented in detail by Poole (1974). The relationship between the cratonic platform and continental shelf east of the axis of the Antler exogeosyncline is clearly delineated (Poole, 1974, fig. 1). During the Early Mississippian, northern Utah was an extensive carbonate shelf between the subsiding foreland trough on the west and the stable cratonic platform on the east. During the Late Mississippian, sedimentation was influenced by eastward transport of clastics, which were beginning to fill the western flysch basin and spill eastward onto the craton.

It would be logical to anchor this present stratigraphic study on the model established by Sando and his co-workers for the cratonic platform and to proceed from east to west. To overcome a possible bias, however, sections were studied in order from southwest to northeast. Distribution of the sections examined is shown on the map (fig. 3). The line of stratigraphic sections is shown graphically in figure 4B. In the view of Sando's (1974) model, a significant thickness of Osagean rocks may have been removed during early Meramecian erosion. The westward change in thickness and facies requires testing of this model through more detailed chronostratigraphy than is now available in the published literature.

A detailed zonation based on conodonts is desirable for the Mississippian biostratigraphy across northern Utah. This would serve at least three purposes. It would supplement the zonation scheme of Sando, Mamet, Dutro (1969) to check and strengthen their model. It would provide a comparison of conodont faunas with lithologies within zones whereby to interpret the paleoenvironmental framework (Sandberg, 1975; Heckel and Baesemann, 1975). The conodont zonation would also give more precise timing for rates of sedimentation, transgression, and regression. Consequently, this preliminary study is an important integral part of the detailed conodont studies and regional stratigraphic studies now being conducted by C. A. Sandberg, F. G. Poole, P. R. Rose, and the writer.

#### LOCALITY REGISTER

The following examined stratigraphic sections are located in figure 3 and shown by graphic cross-section in figure 4B.

#### UTAH

1. Pool Canyon-Dutch Mountain area, Deep Creek Range. Cliff of Madison Limestone and overlying slope on north side of Pool Canyon southeast of Dutch Mountain near lat 40°12'24" N., long 113°51'14" W., Tooele County, in the Gold Hill 1:62,500 quadrangle. Section located from geologic map by Nolan (1935, pl. 1). Highest collection from Madison Limestone is apparently at same location as Girty's collection no. 99 (Nolan, 1935, p. 27).
2. Ochre Mountain, Deep Creek Range. Spur ridges on either side of south-trending canyon south of Ochre Mountain crest at 7,541-foot elevation, Tooele County, in the Gold Hill 1:62,500 quadrangle. Section located from geologic map by Nolan (1935, pl. 1).
3. Skunk Spring Canyon, Confusion Range. Chainman Shale section along draw in N $\frac{1}{2}$ SW $\frac{1}{4}$  sec. 4 and S $\frac{1}{2}$ NE $\frac{1}{4}$ SE $\frac{1}{4}$  sec. 5, T. 18 S., R. 16 W., Millard County, in the Cowboy Pass SW 1:24,000 quadrangle. Section located from geologic maps by Hose and Repenning (1964) and Hintze (1974).



4. Little Mile and a Half Canyon, Confusion Range. Joana Limestone section in  $S\frac{1}{2}NW\frac{1}{4}$  sec. 29, T. 18 S., R. 16 W., Millard County, in the Conger Mountain 1:62,500 quadrangle. Section located from geologic map by Hintze (1974).
5. Buckhorn Canyon, Dugway Range. Along north side of wash in  $SW\frac{1}{4}NE\frac{1}{4}NW\frac{1}{4}$  and  $NW\frac{1}{4}SW\frac{1}{4}NW\frac{1}{4}$  sec. 1, T. 10 S., R. 12 W. (unsurveyed), Tooele County, in the Dugway Range NW 1:24,000 quadrangle. Section located from geologic map by Staatz and Carr (1964, pl. 1).
6. Bullion Canyon, Dugway Range. Cluffed westward-dipping escarpment in  $SE\frac{1}{4}SE\frac{1}{4}$  sec. 27 and  $N\frac{1}{2}NE\frac{1}{4}NE\frac{1}{4}$  sec. 34, T. 9 S., R. 12 W. (unsurveyed), Tooele County, in the Dugway Proving Ground SW 1:24,000 quadrangle. Section located from geologic map by Staatz (1972).
7. Fitchville Ridge, East Tintic Mountains. Fitchville Formation-Gardison Limestone section along crest of northwest-trending ridge in  $NE\frac{1}{4}NW\frac{1}{4}$  sec. 19, T. 10 S., R. 2 W., Juab County, in the Eureka 1:24,000 quadrangle. Section, located from geologic map by Morris (1964, pl. 1), was described by Morris and Lovering (1961, p. 84-85).
8. Mammoth Peak, East Tintic Mountains. Gardison Limestone-Deseret Limestone section above cliff near  $CW\frac{1}{2}NE\frac{1}{4}NE\frac{1}{4}$  sec. 30, T. 10 S., R. 2 W., Juab County, in Eureka 1:24,000 quadrangle. Section, located from geologic map by Morris (1964, pl. 1), was mentioned by Morris and Lovering (1961, p. 89).
9. Rattlesnake Spur of Gardison Ridge, East Tintic Mountains. Southwest-trending ridge in  $NE\frac{1}{4}$  sec. 1, T. 9 S., R. 3 W., Utah County, in the Allens Ranch 1:24,000 quadrangle. Section, located from geologic maps by Proctor and others (1956) and Disbrow (1961), was described by Morris and Lovering (1961, p. 90).

10. Ophir Canyon, Oquirrh Mountains. Type section of Deseret Limestone on north side of canyon in  $SE\frac{1}{4}SE\frac{1}{4}$  sec. 22, T. 5 S., R. 4 W., Tooele County, in the Stockton 1:62,500 quadrangle. Section, located from geologic map by Gilluly (1932, pl. 12), was described by Gilluly (1932, p. 25).
11. Sharp Mountain, Oquirrh Mountains. Great Blue Limestone along north-trending ridge crest in  $W\frac{1}{2}$  sec. 11, T. 5 S., R. 4 W., Tooele County, in the Stockton 1:62,500 quadrangle. Section was located from geologic map by Gilluly (1932, pl. 12).
12. Ogden Canyon, Wasatch Range. Bench atop cliff of Madison Limestone and Deseret Limestone-Humbug Formation section near C  $SW\frac{1}{4}NW\frac{1}{4}$  sec. 16, T. 6 N., R. 1 E., Weber County, in the Huntsville 1:24,000 quadrangle. See Schell and Moore, 1970, p. 10.
13. Cedar Canyon, Wasatch Range. Ridge at head of Metz Hollow in  $NW\frac{1}{4}NE\frac{1}{4}NW\frac{1}{4}$  sec. 30, T. 4 N., R. 3 E., Morgan County, in the Morgan 1:24,000 quadrangle. Section located from geologic map by Mullens and Laraway (1973).
14. Wheat Grass Canyon, Wasatch Range. Along north side of canyon in  $NE\frac{1}{4}NE\frac{1}{4}$  sec. 26 and  $SE\frac{1}{4}SE\frac{1}{4}$  sec. 23, T. 7 N., R. 3 E., Weber County, in the Causey Dam 1:24,000 quadrangle. Section located from geologic map by Mullens (1969). Also see Schell and Moore (1970, p. 11).
15. East Canyon, Bear River Range. South side of canyon along northeast-sloping spur in  $W\frac{1}{2}SW\frac{1}{4}$  and  $N\frac{1}{2}NE\frac{1}{4}SW\frac{1}{4}$  sec. 17 and  $S\frac{1}{2}SE\frac{1}{4}$  sec. 18, T. 9 N., R. 2 E., Cache County, in the Paradise 1:24,000 and Porcupine Reservoir 1:24,000 quadrangles. Section located from geologic map by Mullens and Izett (1964, pl. 1).
16. Blacksmith Fork, Bear River Range. Cliffs of Madison Limestone and Brazer Formation in  $SW\frac{1}{4}SW\frac{1}{4}$  sec. 5, T. 10 N., R. 2 E., Cache County, in the Logan 1:24,000 quadrangle.

17. Leatham Hollow, Bear River Range. Upward continuation of measurements from the type section of the Leatham Formation through the so-called "Chinese Wall" of the Madison Limestone into the Brazer Formation in NW $\frac{1}{4}$ NW $\frac{1}{4}$  sec. 34 and SW $\frac{1}{4}$  sec. 27, T. 11 N., R. 2 E. (unsurveyed), Cache County, in the Logan Peak 1:24,000 quadrangle.
18. Laketown Canyon. North side of Old Laketown Canyon in S $\frac{1}{2}$ NE $\frac{1}{4}$  sec. 32, T. 13 N., R. 6 E., Rich County, in the Laketown 1:24,000 quadrangle. Section located from geologic map by Richardson (1941, pl. 1) and shown graphically by Sando, Dutro, and Gere (1959, fig. 5).
19. Brazer Canyon, Crawford Mountains. Type section of Brazer Dolomite along northwest-trending section from NW $\frac{1}{4}$ SE $\frac{1}{4}$  to NW $\frac{1}{4}$ NW $\frac{1}{4}$  sec. 20, T. 11 N., R. 8 E., Rich County, in the Rex Peak 1:24,000 quadrangle. Section located from geologic maps by Richardson (1941, pl. 1) and Sando, Dutro, and Gere (1959, fig. 2).
20. Warner Hollow, Crawford Mountains. Phosphatic zone in basal part of Brazer Dolomite near C S $\frac{1}{2}$  sec. 31, T. 11 N., R. 8 E., Rich County. Section located from geologic map by Sando, Dutro, and Gere (1959, fig. 2).
21. Dog Valley Mountain, Pavant Range. Along crest of ridge near C S $\frac{1}{2}$  sec. 21, T. 24 S., R. 6 W., Millard County, in the Cove Fort 1:62,500 quadrangle. Overturned section located from geologic map by Crosby (1959, pl. 2).

#### IDAHO

22. Little Flat Canyon--Section 1, Chesterfield Range. Along spur ridge in NW $\frac{1}{4}$  sec. 29, and S $\frac{1}{2}$  sec. 20, T. 7 S., R. 40 E., Bannock County, in the Portneuf 1:62,500 quadrangle. Line of section shown on geologic map by Dutro and Sando (1963, fig. 2).
23. Little Flat Canyon--Section 2, Chesterfield Range. Along spur ridge in NW $\frac{1}{4}$  sec. 20 and C S $\frac{1}{2}$  sec. 17, T. 7 S., R. 40 E., Bannock County, in the Portneuf 1:62,500 quadrangle. Line of section shown on geologic map by Dutro and Sando (1963, fig. 2).

## MISSISSIPPIAN STRATIGRAPHY

The Lower and lower Upper Mississippian succession in northwestern Utah is subdivided into three lithogenetic units. The lower unit is generally cliff-forming Lower Mississippian carbonate rocks variously called Lodgepole Limestone, lower part of Fitchville Formation, and Gardison, Joana, and Redwall Limestones. The middle unit is a sequence of laterally intertonguing Lower and lower Upper Mississippian carbonate and quartz-clastic rocks referred to as Woodman, Deseret, Little Flat, Humbug, and Brazer Formations. The upper unit comprising the Upper Mississippian Ochre Mountain and Great Blue Limestones is mostly carbonate rocks with medial dark shales--the Herat and Long Trail Shale Members. The more clastic Chainman Formation in the Confusion Range is in part equivalent to the Ochre Mountain and Great Blue Limestones.

### Lower Mississippian carbonate rocks

A sequence of dominantly limestone and dolomite beds that are closely related in time and environmental framework lie between Upper Devonian strata and the lower phosphatic zone of the Deseret Limestone (fig. 4B). These stratigraphic units, because of their lithologic differences, are variously called Lodgepole (Madison) Limestone, lower part of Fitchville Formation, Gardison Limestone, Joana Limestone, and Redwall Limestone. The Madison Limestone has its typical exposures in Montana (Sando and Dutro, 1974), Idaho, and Wyoming, so that its affinity is to the north and northeast of the study area. The Gardison Limestone (Morris and Lovering, 1961) is conformable with the underlying Fitchville Formation and both have their typical exposures in the East Tintic Mountains. The topmost member of the Fitchville Formation is the Curly Limestone Member, which is a biostrome of stromatolitic algal limestone (fig. 4B). The distribution of the Curly Limestone given by Proctor and Clark (1956, fig. 1) may well outline the lateral extent of the Fitchville-Gardison sequence.

The Joana Limestone (Chilingar and Bissell, 1957; Langenheim, 1960; Stensaas and Langenheim, 1960) and Redwall Limestone (McKee, Gutschick, and others, 1969), on opposite sides of an area that contains no late Paleozoic rocks (fig. 3), are both related to the Monte Cristo Group to the south. The Redwall Limestone is the equivalent of the Leadville Limestone to the east and southeast in Colorado (Parker and Roberts, 1966). The widespread nodular, fossiliferous, thin-bedded lower unit of the Lodgepole Limestone (late Kinderhookian zone A of Sando, Mamet, and Dutro, 1969) seems to be present also in the lower part of the Joana Limestone in the Dugway Range and elsewhere in Utah and probably extends into southeastern Nevada.

Preliminary observations and speculations suggest that the lower parts of the Joana and Redwall Limestones were formed in shallow water as facies time-equivalents. The fossiliferous limestones are essentially bioclastic undaform deposits. The Lodgepole-type limestone, except for basal zone A, was formed offshore in less oxidizing clinoform environments. The Gardison Limestone probably was formed in a separate shallow basin.

#### Phosphatic shale member of basal Deseret Limestone and equivalent strata

Perhaps the most persistent Mississippian stratigraphic unit across northern Utah is the phosphatic shale member, which lies directly on top of the Lower Mississippian carbonate rocks (figs. 4B, 4C). Because of its possible economic potential, the critical basal part was sought out and trenched for phosphate rock. Sections where phosphorite has been observed are tabulated below, and their distribution is shown in figure 7.

## Mississippian phosphate occurrences in Utah

Sections observed and studied for this report are indicated by \*. Also see locality map (fig. 7) and columnar sections (figs. 4B, 4C).

### Localities

### References

*1. Laketown Canyon, Bear Lake area	Richardson (1941); Cheney (1957); Sandberg (unpubl. section)
*2. Warner Hollow, Crawford Mountains	Sando, Dutro, and Gere (1959, p. 2747); Sandberg (unpubl. section)
3. Providence Canyon, Bear River Range	Cheney (1957)
*4. Leatham Hollow, Bear River Range	
*5. Blacksmith Fork, Bear River Range	Mullens and Izett (1964)
6. Paradise Quadrangle, Bear River Range	Mullens and Izett (1964).
*7. East Canyon, Bear River Range	Mullens and Izett (1964)
8. Dry Lake, Wasatch Range	Williams (1948); Cheney (1957)
*9. Ogden Canyon, Wasatch Range	Blackwelder (1910); Cheney (1957); Schell and Moore (1970); fig. 12
*10. Wheat Grass Canyon, Wasatch Range	Mullens (1969); Schell and Moore (1970); fig. 13
11. Sheep Herd Creek North and South, Wasatch Range	Schell and Moore (1970); Mullens and Laraway (1973)
*12. Cedar Canyon, Wasatch Range	Mullens and Laraway (1973)
13. Beck's Spur, Wasatch Range	Williams (1939, p. 30, citing P. Wilcken); Cheney (1957)
14. City Creek Canyon, Wasatch Range	Granger (1953)
15. Park City region, Wasatch Range	Bromfield (1968)

Mississippian phosphate occurrences in Utah (continued)

- |  |  |
|--|--|
| 16. Cottonwood Canyon area, Wasatch Range                        | Crittenden (1959)  |
| 17. Northwest of Heber   | Baker, Huddle, and Kinney (1949,<br>p. 1174); Cheney (1957)      |
| 18. American Fork area, Wasatch Range                            | Baker, Huddle, and Kinney (1949);<br>Baker and Crittenden (1961) |
| 19. Flux Canyon, Stansbury Mountains                             | Sandberg (oral commun., September<br>1975)                       |
| *20. Ophir Canyon, Oquirrh Mountains                             | Gilluly (1932); figs. 8, 9                                       |
| 21. East Tintic region, East Tintic<br>Mountains (several mines) | Cheney (1957); Morris and Lovering<br>(1961); Morris (1964)      |
| *22. Mammoth Peak, East Tintic Mountains                         | Figs. 10, 11   |
| 23. Mount Nebo, Wasatch Plateau                                  | Cheney (1957)  |
| *24. Buckhorn Canyon, Dugway Range                               | Fig. 6   |
| *25. Dog Valley Mountain, Pavant Range                           |  |
| *26. Skunk Spring Canyon, Confusion Range                        | Fig. 14  |

Observed details of measured sections are shown graphically for: the basal Woodman Formation overlying the Joana Limestone in the Dugway Range (fig. 6); the type section of the Deseret Limestone in Ophir Canyon in the Oquirrh Mountains (figs. 8, 9); the Mammoth Peak section of the Deseret in the East Tintic Mountains (figs. 10, 11); the Ogden Canyon section of the Deseret in the Wasatch Range (fig. 12); and the Wheat Grass Canyon section of the Deseret in the Causey Dam area (fig. 13). Note that the phosphatic unit is also present on top of the Redwall Limestone in the Pavant Range and locally in the basal Brazer Dolomite on top of the Lodgepole Limestone in the Crawford Mountains (fig. 4B, 4C). Similar facies of mudstone and dark-gray chert layers without observed phosphorite occurs in the basal Woodman Formation in the Pool Canyon section in the Gold Hill area (fig. 5).

Lithologies found in association within the phosphatic zone are:

1. Phosphate rock or phosphorite, <sup>glaucconitic,</sup> /dark-brownish-gray, oolitic, peloidal, pisolitic, pebbly; with traces of vanadium, zinc, nickel, lanthanum, yttrium, chromium, and possibly other metals (Morris and Lovering, 1961; Schell and Moore, 1970).
2. Shale, phosphatic, dark-brownish-gray, possibly metalliferous, organic-carbonaceous and bituminous. Likely source rock for hydrocarbons along with phosphorite.
3. Chert, dark-gray, nodular to bedded, spiculitic, radiolarian; commonly containing oolitic or peloidal phosphorite.
4. Mudstone, light-olive-gray; commonly containing fine hematite streaks, partly calcareous; commonly jointed with blocky fracture.
5. Limestone, dark-gray, fine-grained; weathering light bluish gray; containing dark-gray nodular cherts.

The shale and mudstones commonly weather to bright pink, lavender, orange, red, and brown oxidation colors that reflect their geochemical composition. These oxidation colors are well displayed in the lower beds of the Deseret Limestone in the Ophir Canyon section. The lithologies, weathering characteristics, and vegetated slope exposures are reminiscent of the phosphorite outcrops in the Permian Phosphoria Formation and related rocks of Idaho, Montana, Wyoming, and Utah.

Graphic sections are included to indicate detailed stratigraphic relationship of the phosphatic facies, to show distribution percentages of phosphorite in relation to other lithologies, and to suggest close correlation between individual beds and sequences between sections. (Compare figs. 8 and 10; 12 and 13.) The maximum thickness of phosphorite is developed in the Wheat Grass and Ogden Canyon sections. In other sections there seems to be more layered dark chert, which may suggest a reciprocal relationship between phosphorite and chert.



Whether this phosphatic facies, which is generally sandwiched between thick carbonate successions, represents a shallow or deep-water environment is problematic. The abrupt sharp change from carbonate to the phosphatic facies implies a rapid, radical change in environments, but the conodont evidence suggests that the basal contact is conformable. The environment may be similar, if not identical, to that of the Permian Phosphoria Formation. Upwelling of colder, deeper water along a marine shelf slope has been advocated for the latter (McKelvey and others, 1959; McKelvey, 1959). A basin-shelf model has been postulated for Upper Devonian black shales across New York State. These nonbioturbated dark shales were formed under anoxic basin conditions with pelagic sedimentation (Byers, 1973). Black shales of Upper Pennsylvanian megacyclothems in eastern Kansas, containing phosphorite laminae and nodules in the absence of benthonic fossils, represent the deepest water and most anoxic conditions during the height of marine transgression (Heckel and Baesemann, 1975, fig. 6). Inarticulate lingulid and orbiculoid brachiopods, Leiorhynchus carboniferum, and goniatite cephalopods have been reported and observed in dark shales in the phosphatic zone in Utah, but the physicochemical and biologic evidence for the origin and precise age of the containing rocks has been equivocal.

#### Woodman, Deseret-Humbug, and Brazer sequence

The Woodman Formation (Nolan, 1935, p. 27), Deseret Limestone (Gilluly, 1932, p. 25), Humbug Formation (Tower and Smith, 1899, p. 625), and Brazer Dolomite (Richardson, 1941, p. 22) represent a series of carbonate and clastic sediments that exhibit much lateral gradation. The detailed biostratigraphy of these rocks has not been established, so that more precise dating and resolution of their lateral time-rock relations is needed. The basal phosphatic zone is common to all except the Humbug Formation, which overlies the Deseret Limestone in its type area. The source and distribution of substantial quantities of quartz clastics above this phosphatic zone have not been firmly determined.

The Woodman Formation in the Deep Creek and Dugway Range localities consists of calcareous siltstones and sandstones in the lower part and silty sandy limestones in the upper part. Fossiliferous encrinite beds occur within the Woodman in the Pool Canyon and Ochre Mountain sections of the Gold Hill area. The Deseret Limestone is mainly dark-gray silty fossiliferous partly cherty limestone above the basal phosphatic member in the Ophir and Eureka areas. The Deseret becomes much more sandy and dolomitic to the northeast. The Humbug Formation is predominantly partly calcareous siltstone and sandstone with some carbonate units. There is lateral gradation of the Deseret-Humbug sequence so that the formations become difficult to separate to the northeast. Equivalent strata in the northern Wasatch and Bear River Ranges are called Brazer Formation. The lower part of the Brazer there contains a phosphatic member with phosphorite, dolomite, and dark chert comparable to that of the lower Deseret. The type Brazer Dolomite in the Crawford Mountains is entirely dolomite except for very minor amounts of clastic material. Lithologically the Little Flat Formation of southeastern Idaho (Dutro and Sando, 1963) resembles the Humbug Formation in Ophir Canyon and the Woodman Formation in the Gold Hill area.

#### Ochre Mountain Limestone, Great Blue Limestone, and Chainman Shale

The Ochre Mountain Limestone (Nolan, 1935, p. 29) in the Deep Creek and Dugway Ranges and the Great Blue Limestone (Spurr, 1895, p. 374) in the Oquirrh and East Tintic Mountains consist of a lower carbonate member, a middle dark shale member (Herat or Long Trail Shale Members), and an upper carbonate member. The two thick (approximately 2,500 to > 4,000 ft or 760 to > 1,220 m) limestone sequences are apparently part of the same Upper Mississippian lithosome. If they are exactly correlative, the Great Blue Limestone has priority.

In the East Tintic Mountains, the Great Blue Limestone has been divided into . four mappable members (Morris and Lovering, 1961; Morris, 1964). The lowest Topliff Limestone Member and overlying Paymaster Member are dark-gray, fine- to medium-grained, partly cherty limestones, which weather light bluish gray. The next higher member is the Chiulos, which consists of olive and black shale with minor interbedded quartzite. The Poker Knoll Limestone Member at the top is light-gray, fine-grained, cherty limestone. In the Ophir district, bedded replacement-type ore bodies occur in the fossiliferous uppermost part of the lower Great Blue Limestone.

In the Confusion Range, rocks equivalent to the Ochre Mountain and Great Blue Limestones are represented by the Chainman Shale (fig. 4B), which has been subdivided into five members by Sadlick (1965). The lowest member is the Needle Siltstone, which is overlain by the dark-gray, fine-grained Skunk Spring Limestone. Next in ascending order is the Camp Canyon Member. (The Willow Gap Limestone and Jensen Members at the top were not studied in detail.) The Chainman Shale is overlain by the Pennsylvanian Ely Limestone. The lower part of the Camp Canyon Member has dark-gray organic shale, large dark-gray, fine-grained phosphatic(?) limestone concretions and concretionary limestone layers with goniatite cephalopods (lower Goniatites zone of Gordon and others, 1957; lower two goniatite zones of Gordon, 1970), and thin calcareous siltstone layers with Leiorhynchus carboniferum and lingulid and orbiculoid brachiopods (fig. 14). Peloidal phosphate rock occurs in this zone in a bed enveloping one of the large concretions with goniatites (fig. 14, upper part). Thus, this culm-type facies association consists of: dark organic, possibly phosphatic, shale with palynomorph-rich layers that are probable source beds (Poole and others, 1975); large and small phosphatic concretions commonly containing goniatites and liquid oil; brownish-gray peloidal phosphorite, which may also have organic carbon in close association with the concretions surrounding them; isolated goniatites in the dark shales; and dark-brownish-gray calcareous siltstone containing brachiopods. Layered and nodular dark cherts, common in the phosphatic facies of the basal Deseret Limestone and Phosphoria Formations, were not observed in the Confusion Range.

Distribution of the Ochre Mountain and Great Blue Limestones approximates the area within the 5,000-foot isopach circumscribing the Oquirrh Basin (fig. 1A). Carbonate deposition took place within this deepening basin, which apparently was little affected at that time by Antler orogenic flysch sediments from the west. Bissell and Klopp (1975) indicated that the carbonate is a deep-water accumulation in a depocenter within the Cordilleran miogeosyncline. This <sup>supposed</sup> intrabasinal carbonate sedimentation was succeeded by extrabasinal flysch derived from Antler Highlands which filled the foreland basin and spilled eastward into the Oquirrh Basin (Poole, 1974). On the other hand, the Chainman Shale is mostly Antler orogenic flysch, which was succeeded by carbonate deposition of the Ely Limestone during the Pennsylvanian.

#### ECONOMIC POTENTIAL OF GREAT BLUE LIMESTONE

A remarkable analogy exists between mineralization in the Mercur and Ophir Canyon districts at the south end of the Oquirrh Mountains and the structural accumulation of petroleum. If migrating hydrocarbon gases are equated with mineralizing solutions, then the principles governing entrapment of relatively low temperature sediment-related hydrocarbons and those governing emplacement of hydrothermal metalliferous solutions are very similar. For localized concentrations with economic potential, both require:

1. SOURCE for oil and gas from organic-rich sedimentary rocks and for mineralizing hydrothermal solutions from intrusive igneous bodies.
2. GEOLOGIC STRUCTURES, such as anticlines and domes, into which low specific gravity migrating hydrocarbon fluids and gasses or metalliferous hydrothermal solutions may rise gravitationally.
3. RESERVOIR ROCKS with porosity and permeability to contain the migrating hydrocarbon fluids and gasses or mineralizing solutions, except that replacement is physicochemically important for mineralizing solutions.

4. IMPERVIOUS SEAL as an enclosing trap over the reservoir-structure to restrict further upward movement of hydrocarbon fluids and gasses or mineralizing solutions.

The Mono mine and the Lion Hill area mines in the Ophir district and the Mercur area mines in the Camp Floyd district are located along or near the crest of an asymmetrical elongate anticline and partly faulted domal structure near Ophir, Utah (Gilluly, 1932, pl. 12). The ore bodies are essentially bedded replacement of the lower Great Blue Limestone directly below the Long Trail Shale Member, although mineralized fissure veins and pipes are also present. The mineralizing hydrothermal solutions possibly emanated from igneous bodies such as the Ophir stocks. The ores yield the metals gold, mercury, silver, lead, zinc, and copper.

Paleozoic sediments were deposited in the Oquirrh Mountains area from Cambrian to Pennsylvanian time. Probably during the Laramide orogeny in Late Cretaceous and early Tertiary, folding occurred to form the north-northwest trending Ophir anticline. The folding was followed shortly by volcanism and emplacement of igneous intrusions, which may have caused Basin-and-Range-type faulting and formation of the faulted dome northwest of Ophir. This complex structural development and attendant metamorphism was climaxed by late stages of hydrothermal activity, and the mineralizing solutions pervaded the fracture systems upward until they were blocked by impervious shale of the Long Trail Shale Member high on the structure. Lateral replacement of the lower Great Blue Limestone directly below the shale resulted in bedded ore bodies. Aureoles of jasperoid or silicified limestone with minor amounts of iron formed around the ore bodies and serve as exploration ore guides (Morris and Lovering, 1961, p. 24).

The principle of mineralizing solutions can be applied to assess the potential of the phosphorites and organic carbonaceous dark shales of the lower part of the Deseret Limestone as source beds for hydrocarbons. Numerous porous reservoir rocks into which the hydrocarbons could have migrated are present in the carbonate rocks that overlie the phosphatic shale member of the Deseret. Favorable structural and(or) stratigraphic traps with adequate seals are required for oil and gas accumulations. However, the Long Trail Shale Member might have provided an effective seal for petroleum as well as for mineralizing solutions.

The above analogy and brief summary may be oversimplified, but its economic potential should not be overlooked. Careful stratigraphic and detailed paleontological and geochemical analyses of Mississippian strata across northern Utah can assist greatly in exploration for mineral deposits as well as for oil and gas reservoirs.

#### SUMMARY

The critical problem is to identify Osagean rocks in northern Utah and determine their thickness. From these data, assessment of their economic potential in terms of petroleum and mineral resources can be made with greater assurance. This report reviews the literature, but it is primarily based on field observations and study. The conclusions are preliminary, because the laboratory paleontological and petrographic studies have not been completed yet.

The field reconnaissance provided an opportunity to observe the stratigraphic relations of important Mississippian sections in northern Utah. The broad regional perspective was preferred over a detailed study of a few sections because of the limited time available. Most attention was given to the upper part of Lower Mississippian rocks and the lower part of Upper Mississippian rocks. This attention focused on the critical Osagean to middle Meramecian sequence.

The Lower Mississippian carbonate rocks are traceable for long distances, although formation names and lithologies change from place to place. Likewise, the basal phosphatic zone of the Deseret Limestone and equivalent rocks is a consistent marker bed across the State of Utah. The Woodman, Deseret, Humbug, Brazer, and Little Flat Formations seem to be related in age and provenance of clastics. This clastic sequence is bounded by thick carbonate units below (the Joana, Lodgepole, Gardison, and Redwall Limestone) and above (the Ochre Mountain and Great Blue Limestones).

An important objective was to collect as many conodont samples from favorable lithologies as possible to aid in zonation, correlation, and environmental interpretation of the rocks. Conodonts were often seen in the field in collected samples, and preliminary conodont studies by Sandberg indicate that many of such samples will be productive. Other samples were collected for organic-carbon content and spectrographic analysis, but these samples have not been processed yet.

Stratigraphic/<sup>data</sup>were collected to test the Sando (1974) model of transgression, regression, and early Meramecian erosional karst unconformity (fig. 2). Information also can be compared with Poole's (1974) Antler orogenic flysch model. Much additional work on the physical stratigraphy remains to be done; however, greater control of time planes based on conodont zonation will facilitate understanding of the geologic history of these rocks.

The Mississippian sequence is thick (fig. 1A), the lithologies are diverse, and megafossil faunas are relatively numerous. However, the probability of finding many more microfaunas is high, and more diligent search and collecting will be needed to fill the gaps in biostratigraphic knowledge.

## RECOMMENDATIONS FOR FURTHER STUDY

It is recommended that four or five of the best exposed, most complete key Mississippian sections across the State of Utah be examined and studied in more detail. The sections already reconnoitered for this report (fig. 4B) that might prove most useful for a detailed biostratigraphic study are: (1) a section in the Bear River Range, either in the East Canyon area or Blacksmith Fork area (Mullens and Izett, 1964); (2) a section in the Ophir Canyon and Dry Canyon-Sharp Mountain areas in the Oquirrh Mountains (Gilluly, 1932); (3) a section in the Eureka or Allens Ranch quadrangle in the East Tintic Mountains (Morris and Lovering, 1961; Morris, 1964; Proctor and others, 1956); (4) a section in Buckhorn and Bullion Canyons in the Dugway Range (Staatz and Carr, 1964; Staatz, 1972); and (5) a section in the Pool Canyon-Dutch Mountain and Ochre Mountain areas in the Gold Hill mining district of the Deep Creek Range (Nolan, 1935). There may be some unvisited sections, especially in the Wasatch Range, that might substitute for or supplement one in the Bear River Range.



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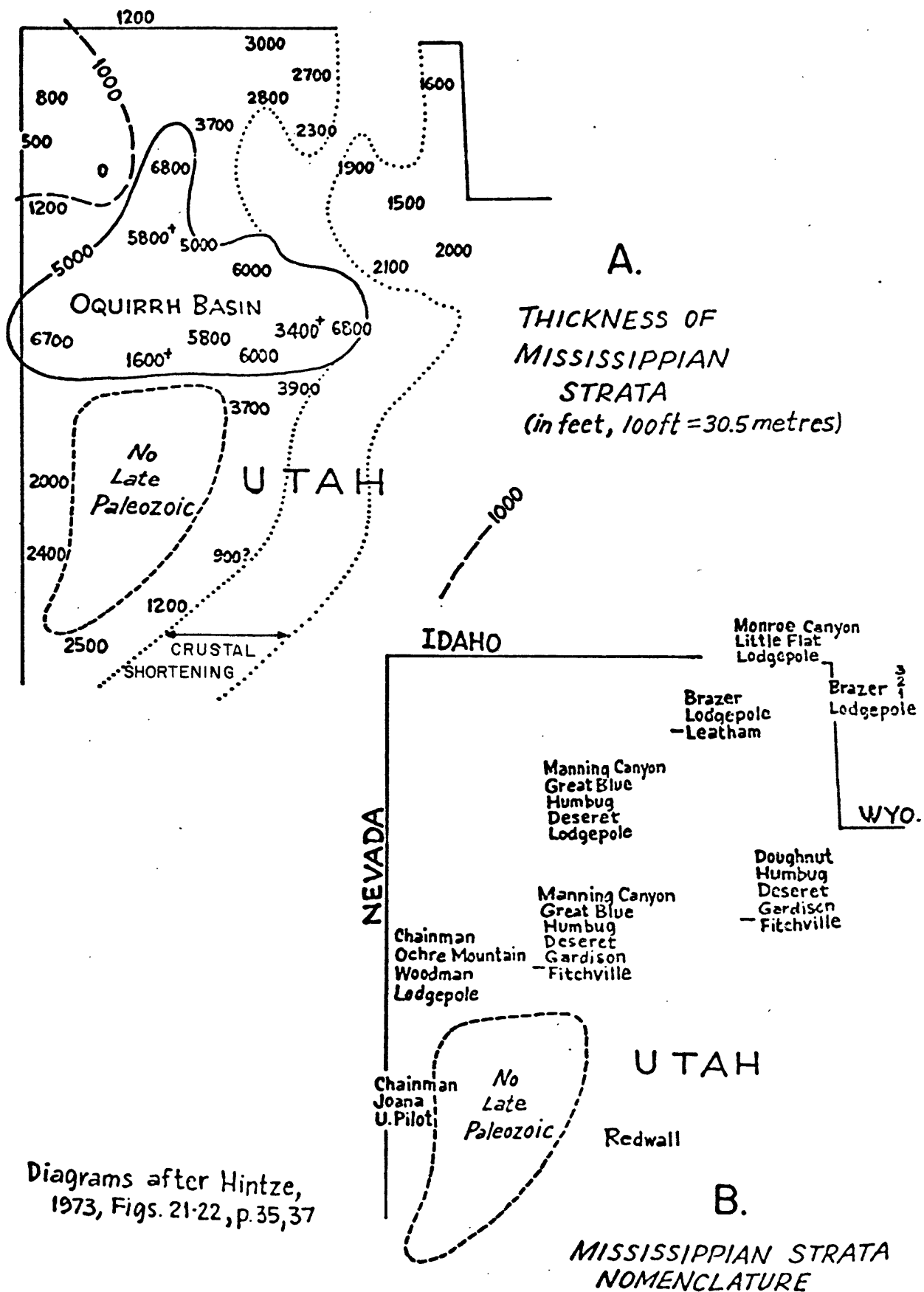


Figure 1.--Mississippian strata of northwestern Utah (Hintze, 1973)

- A. Distribution and thickness of deposits (in feet)
- B. Nomenclature used in stratigraphic sections

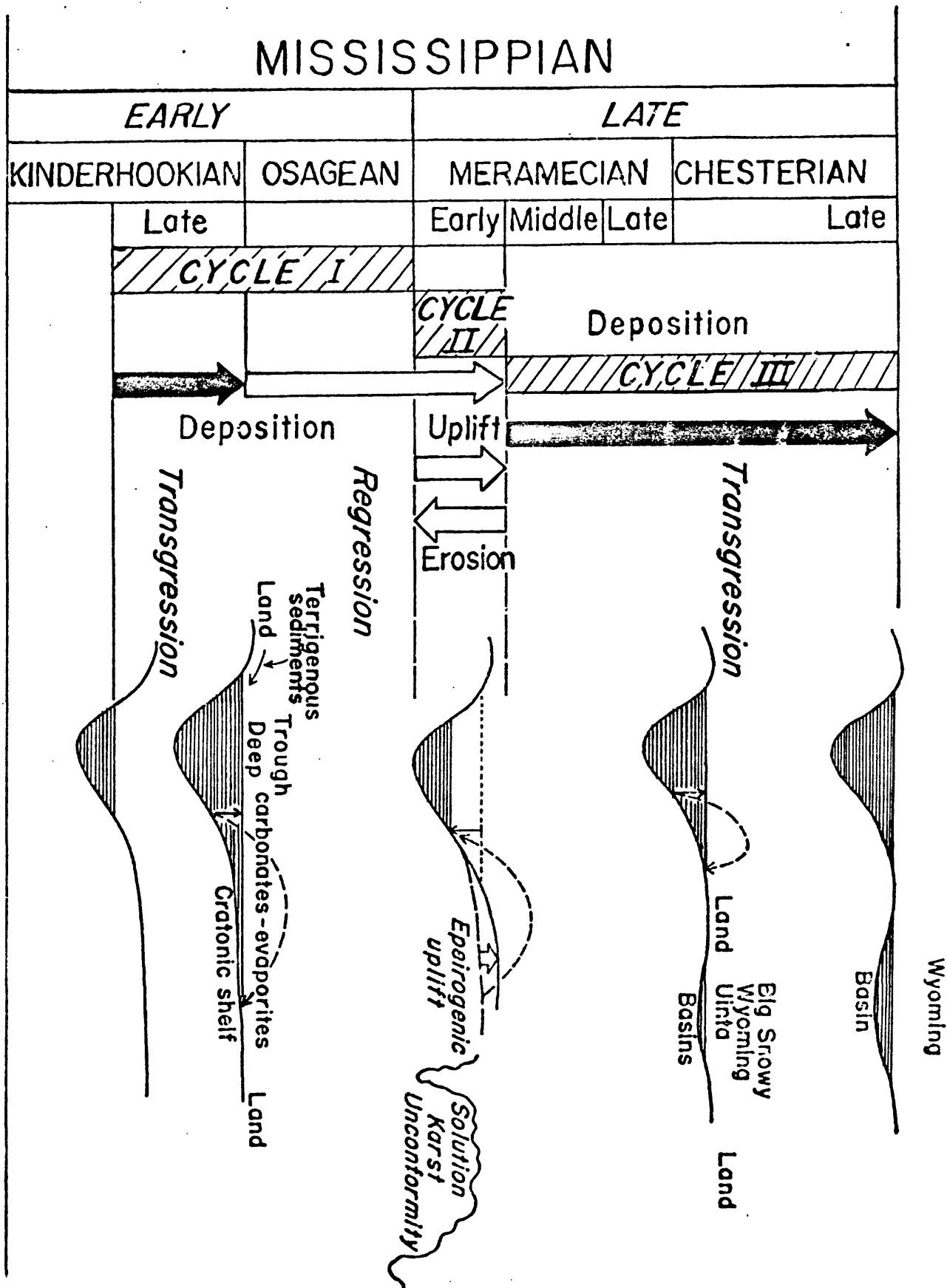


Figure 2.--Diagram of Mississippian history of the Northern Rocky Mountains (based on Sando, 1974).



Fig. 3

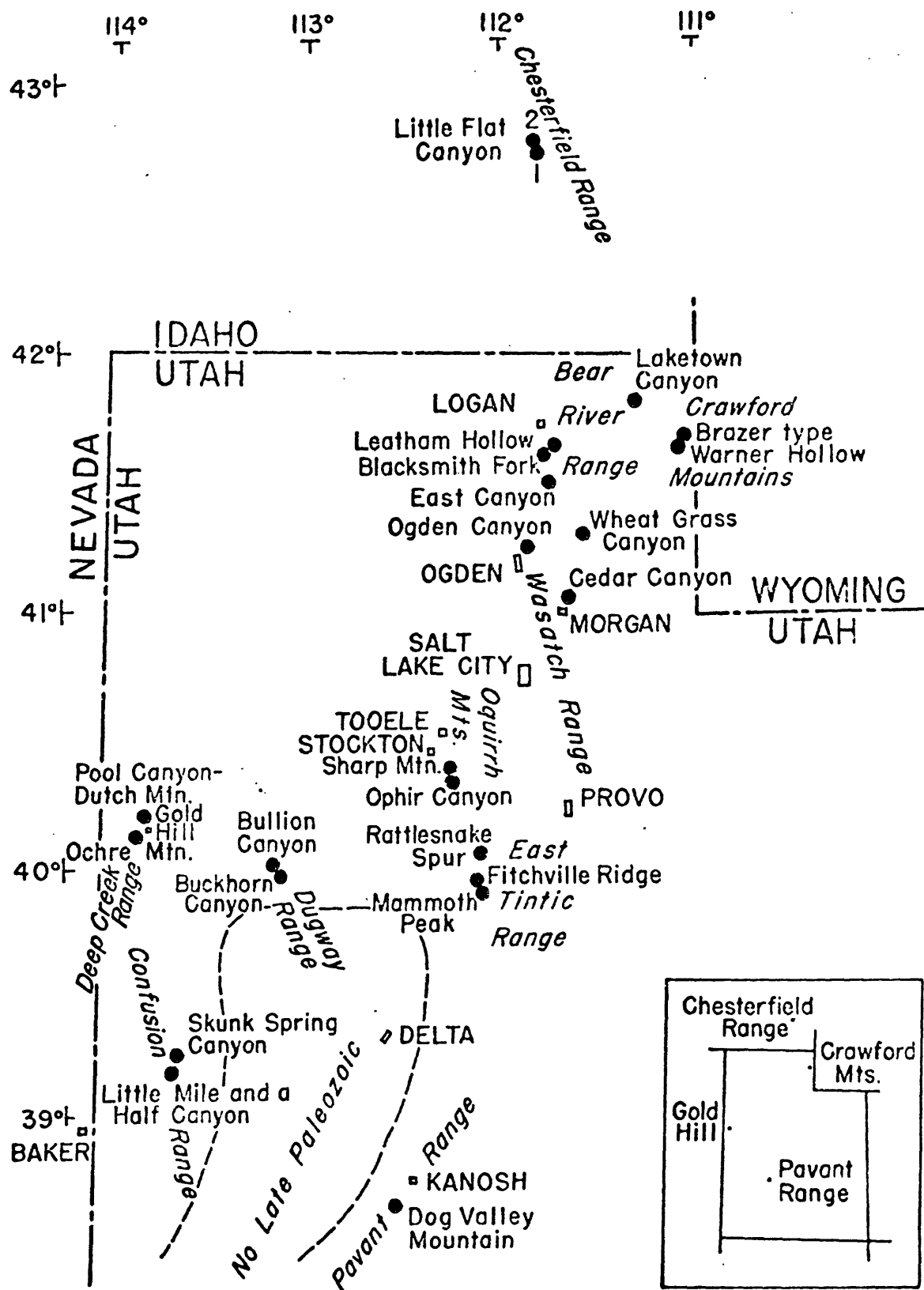


Figure 3.--Location of section localities visited

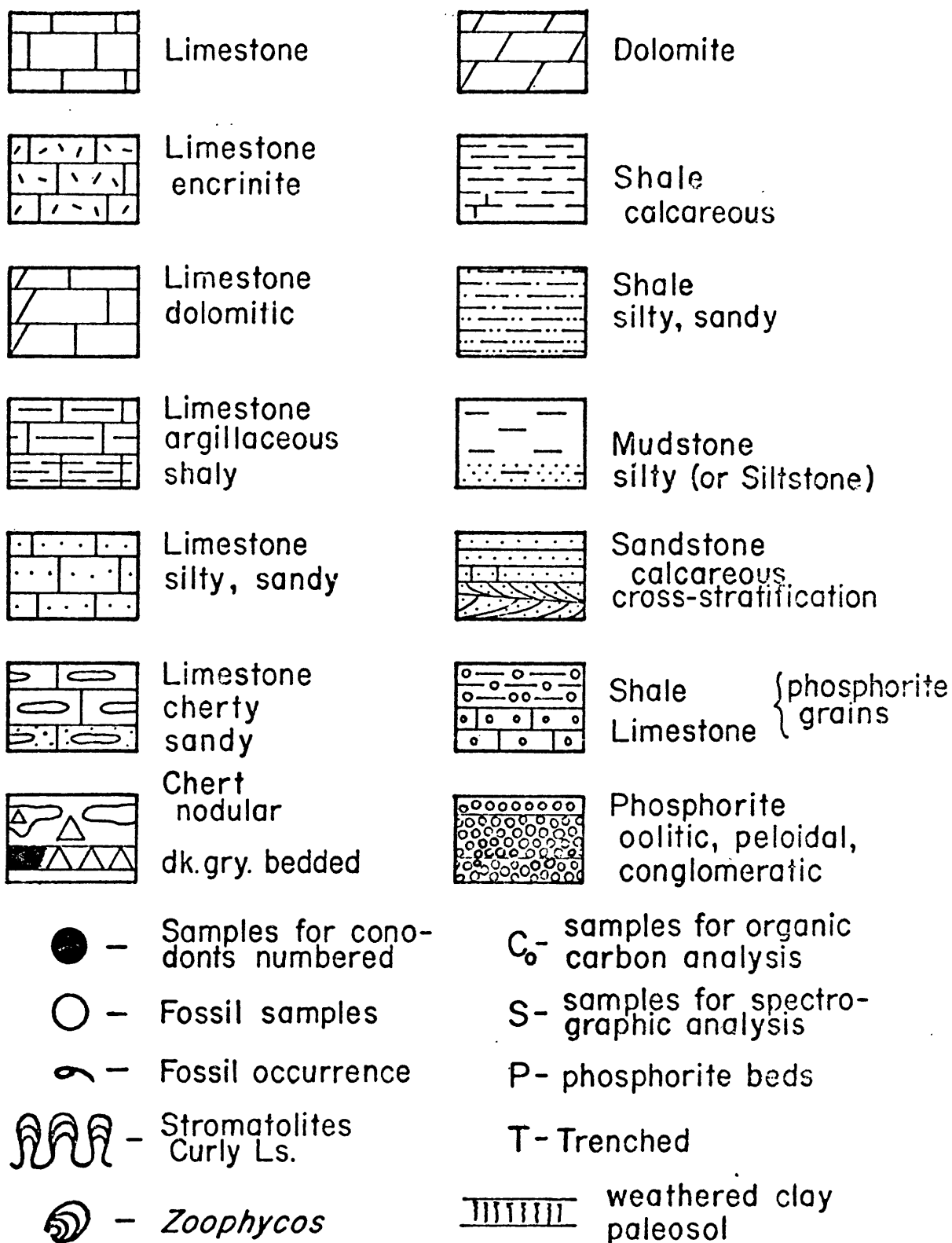


Figure 4A.--Geologic symbols used for columnar and cross sections.

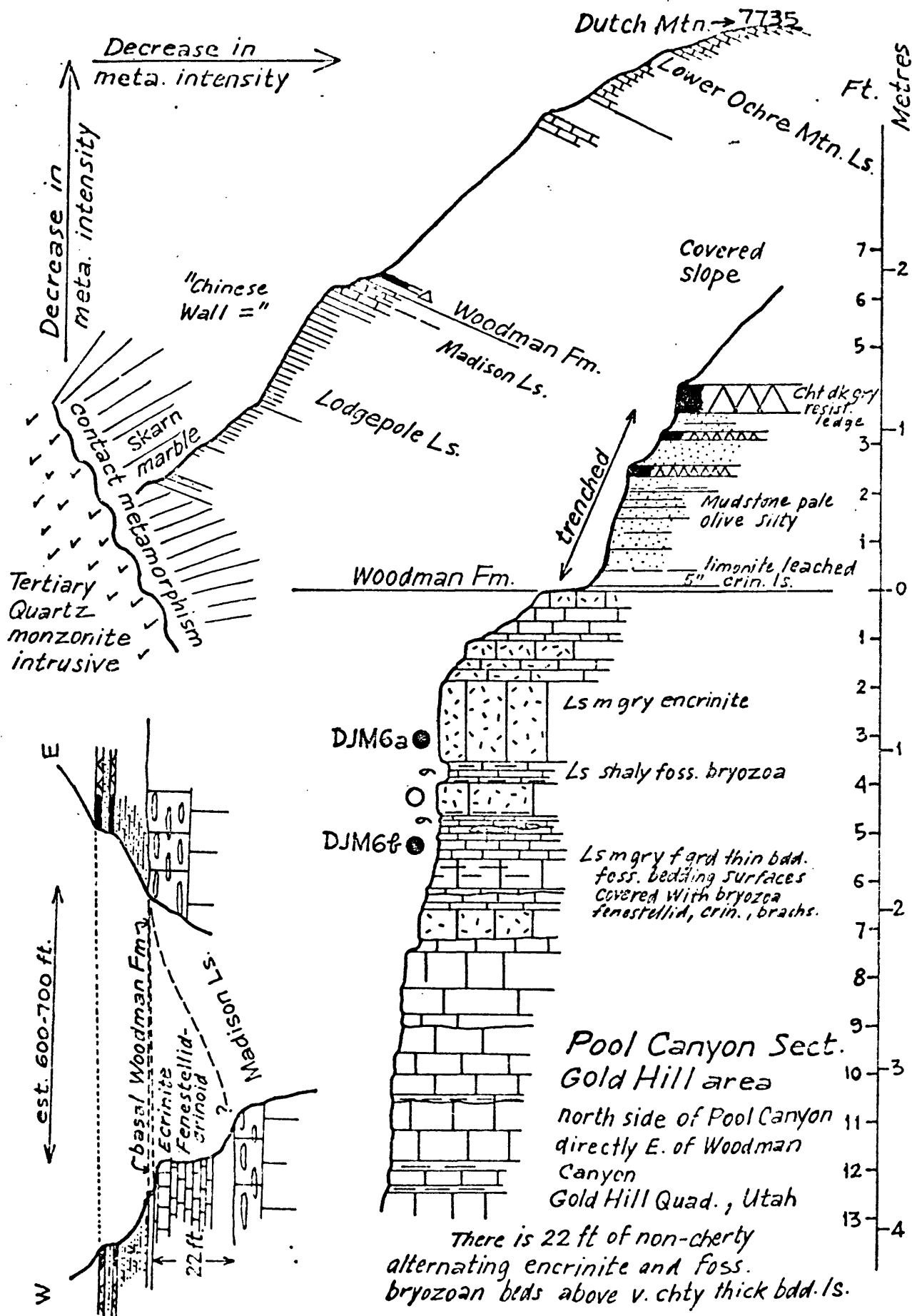


Figure 5.--Stratigraphic relations of Mississippian rocks in Pool Canyon, Gold Hill area, western Utah. Detailed section shows Madison-Woodman contact relationship.

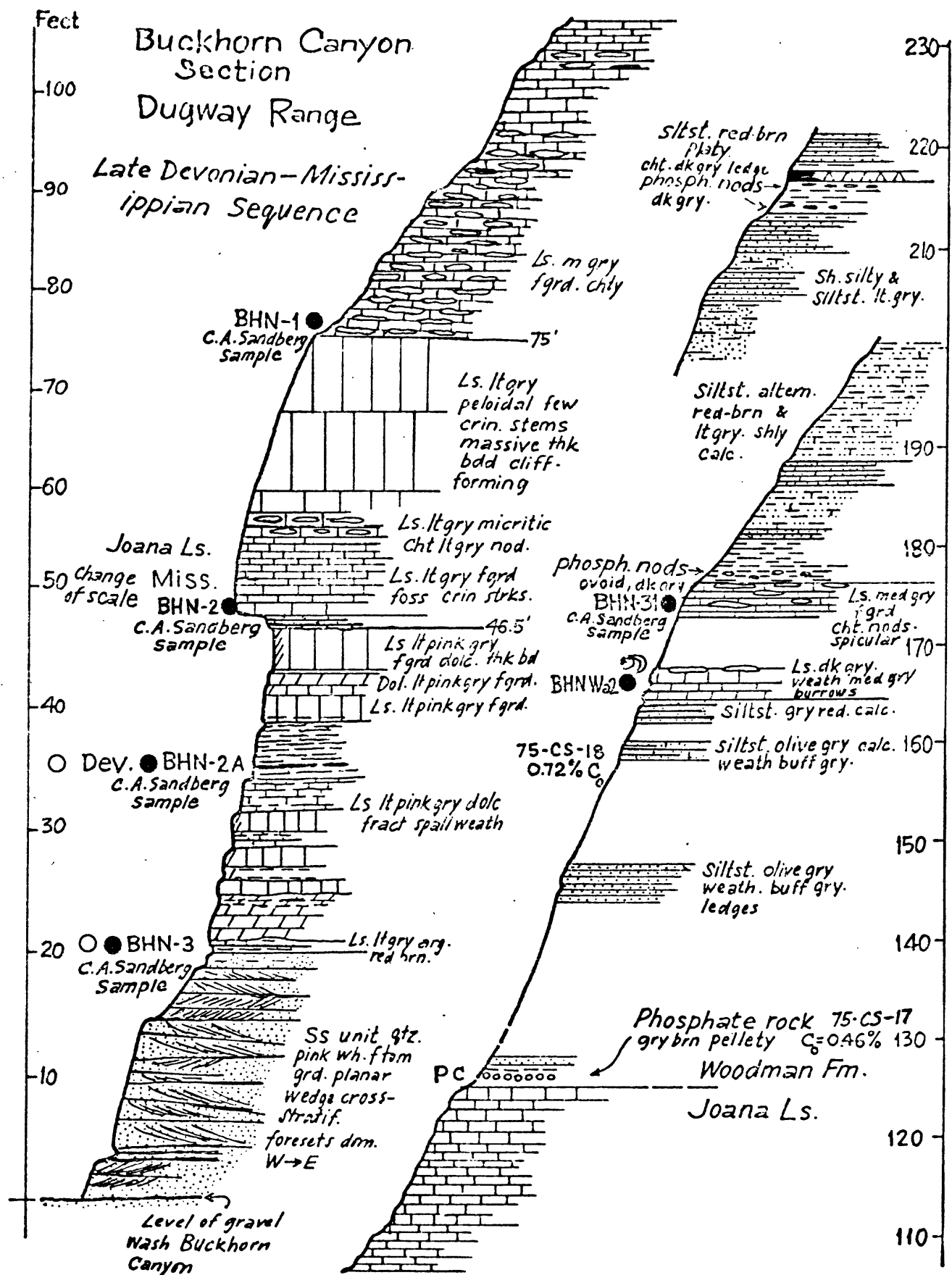
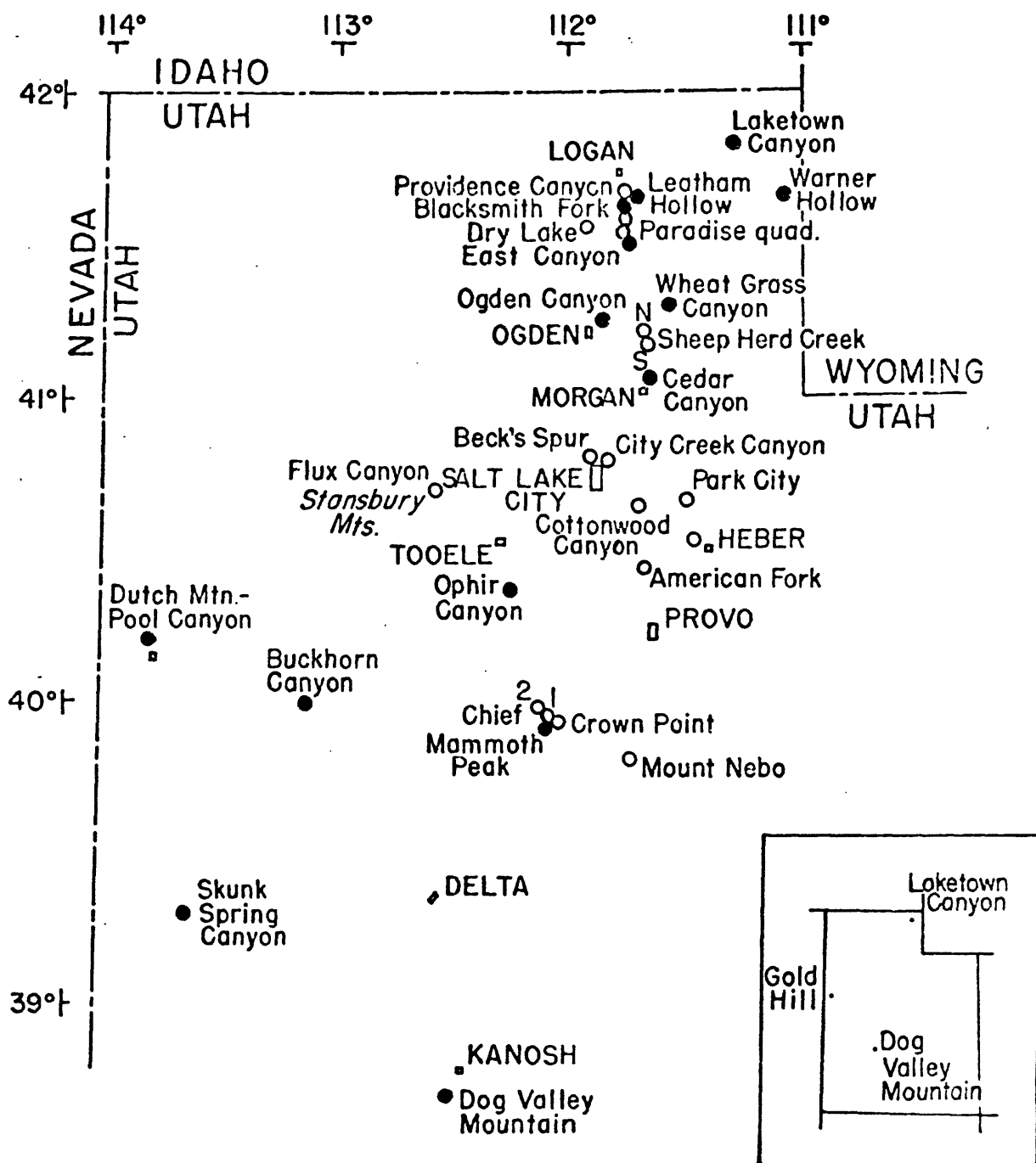


Figure 6.--Joana Limestone-lower Woodman Formation sequence, Buckhorn Canyon section, Dugway Range, Utah.



## MISSISSIPPIAN PHOSPHATE LOCALITIES

Figure 7.--Mississippian phosphatic zone localities in lower part of Deseret Limestone and equivalent strata (except for Skunk Spring Canyon occurrence, see fig. 14), northwestern Utah. Solid circle, locality examined and trenched for this study; open circle, locality from the literature.

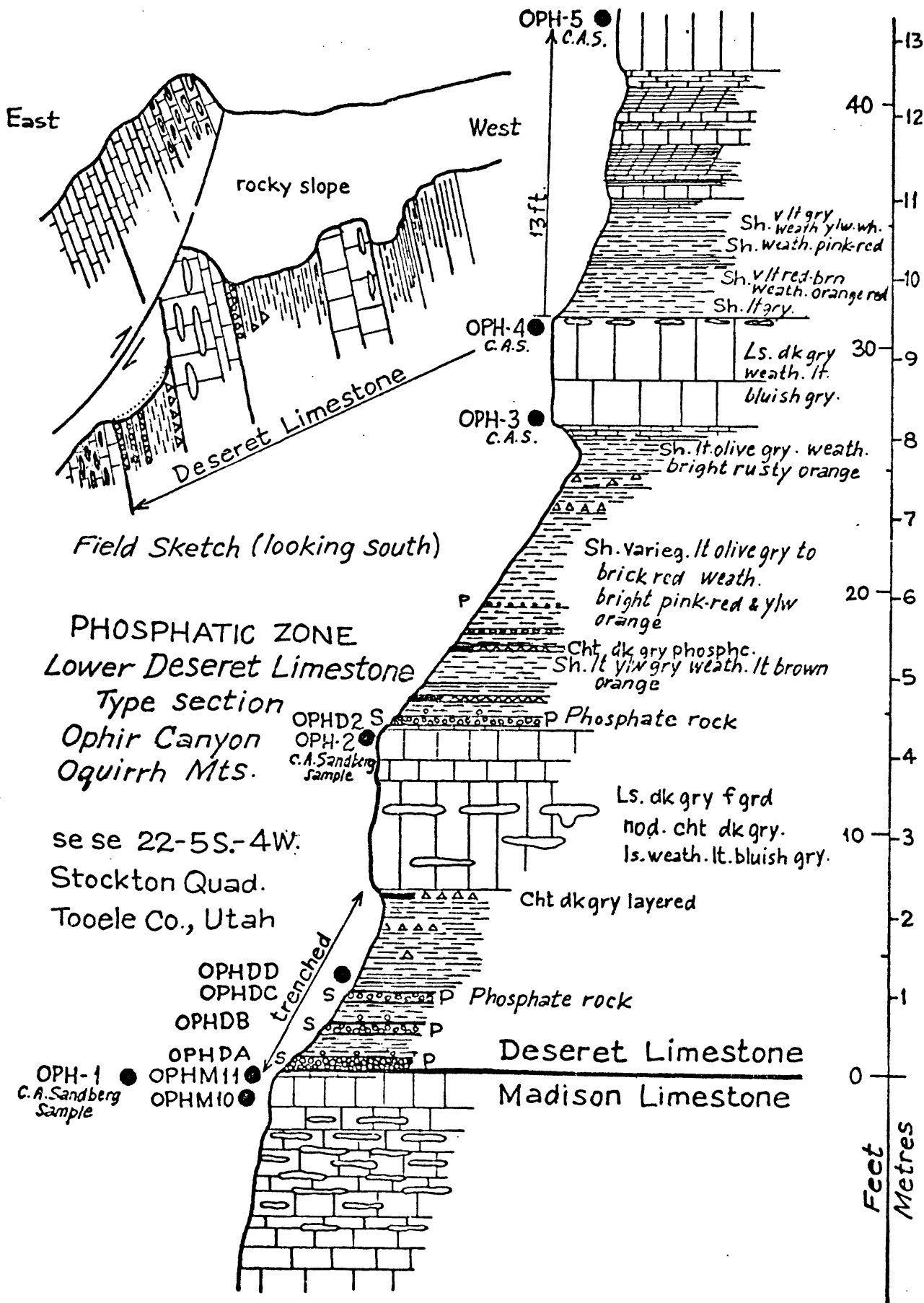


Figure 8.--Lower phosphatic member and structural-stratigraphic relations of type Deseret Limestone, Ophir Canyon, Oquirrh Mountains, Utah.

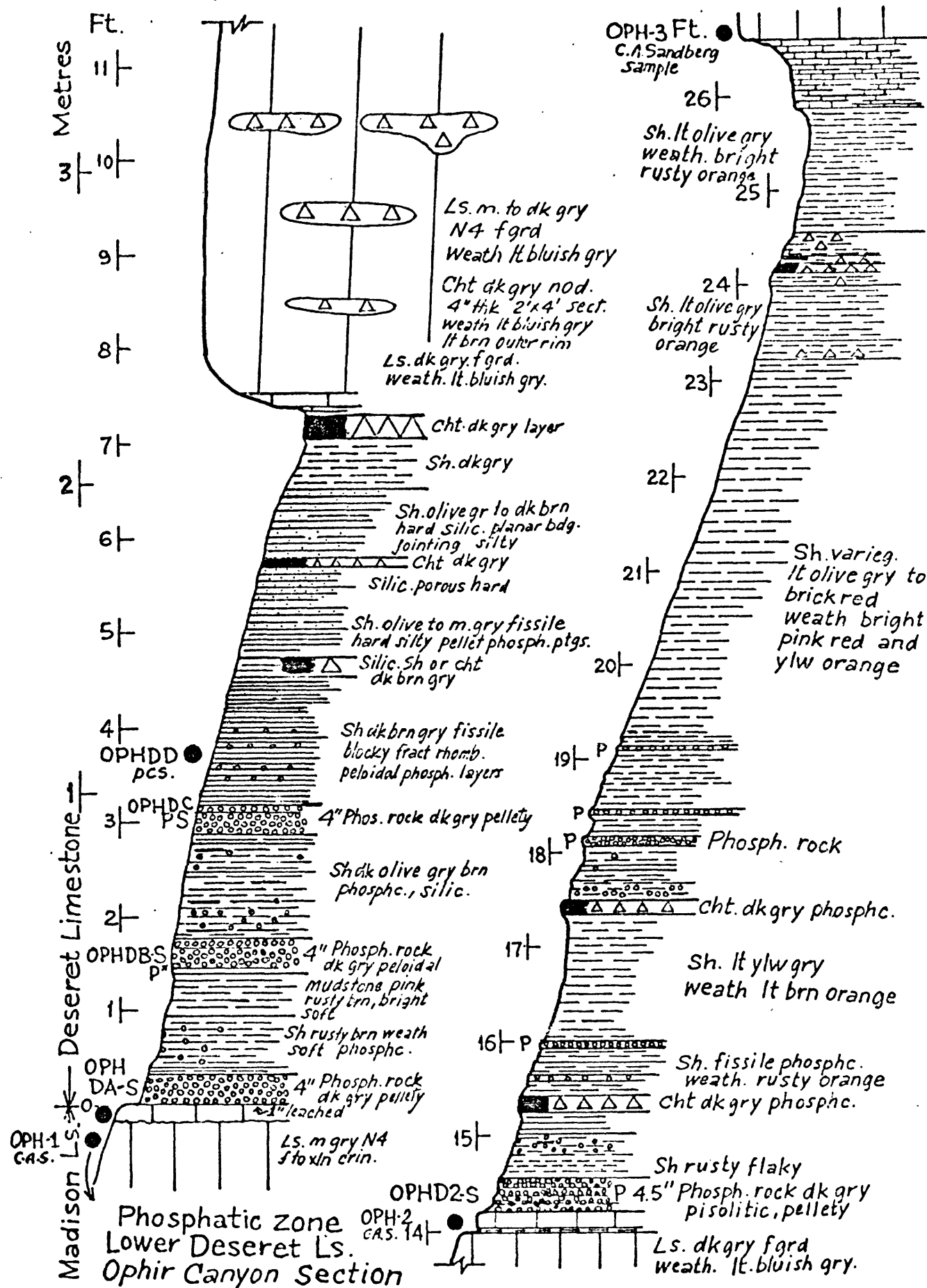


Figure 9.--Detailed measured section of phosphatic member of type Deseret Limestone, Ophir Canyon, Oquirrh Mountains, Utah.

*Phosphatic Zone Lower Desert Ls.*

*Mammoth Peak Section*

*East Tintic Area*

*SWNE 30-10S-2W*

*Eureka Quad.*

*Juab Co., Utah*

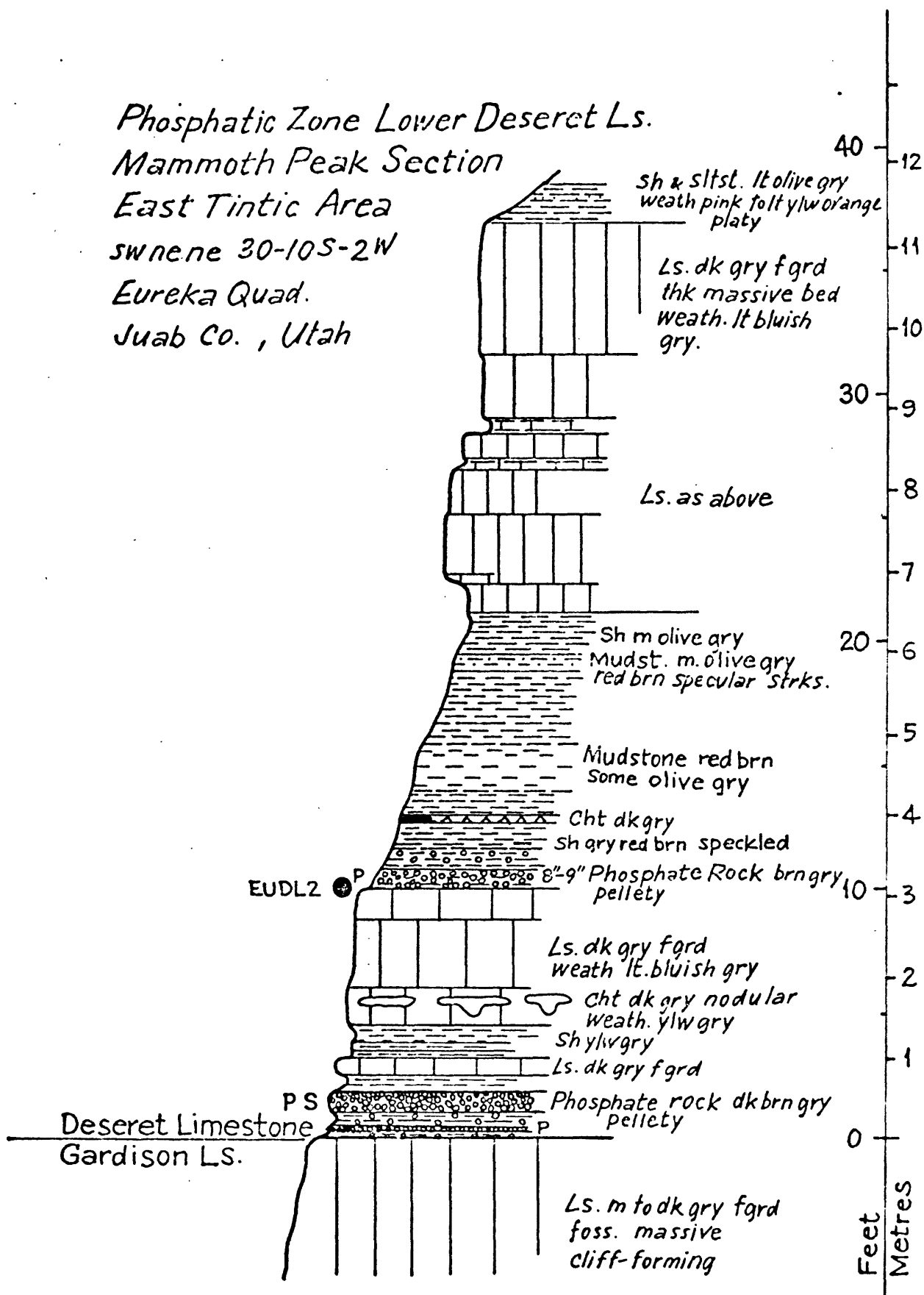


Figure 10.--Lower Desert phosphatic zone, Mammoth Peak section, East Tintic Mountains, Utah.



# Lower Deseret Limestone East Tintic Area, Utah

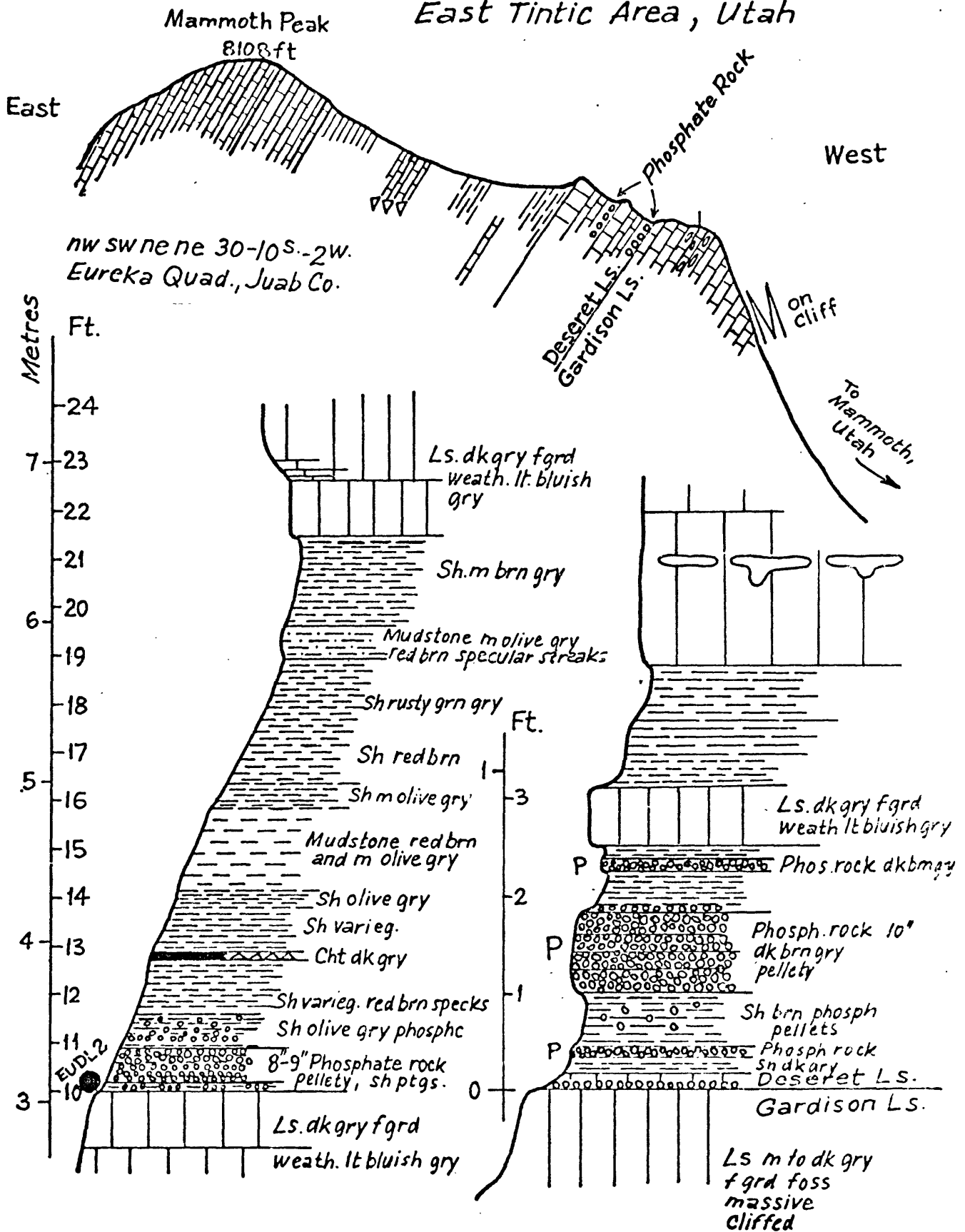
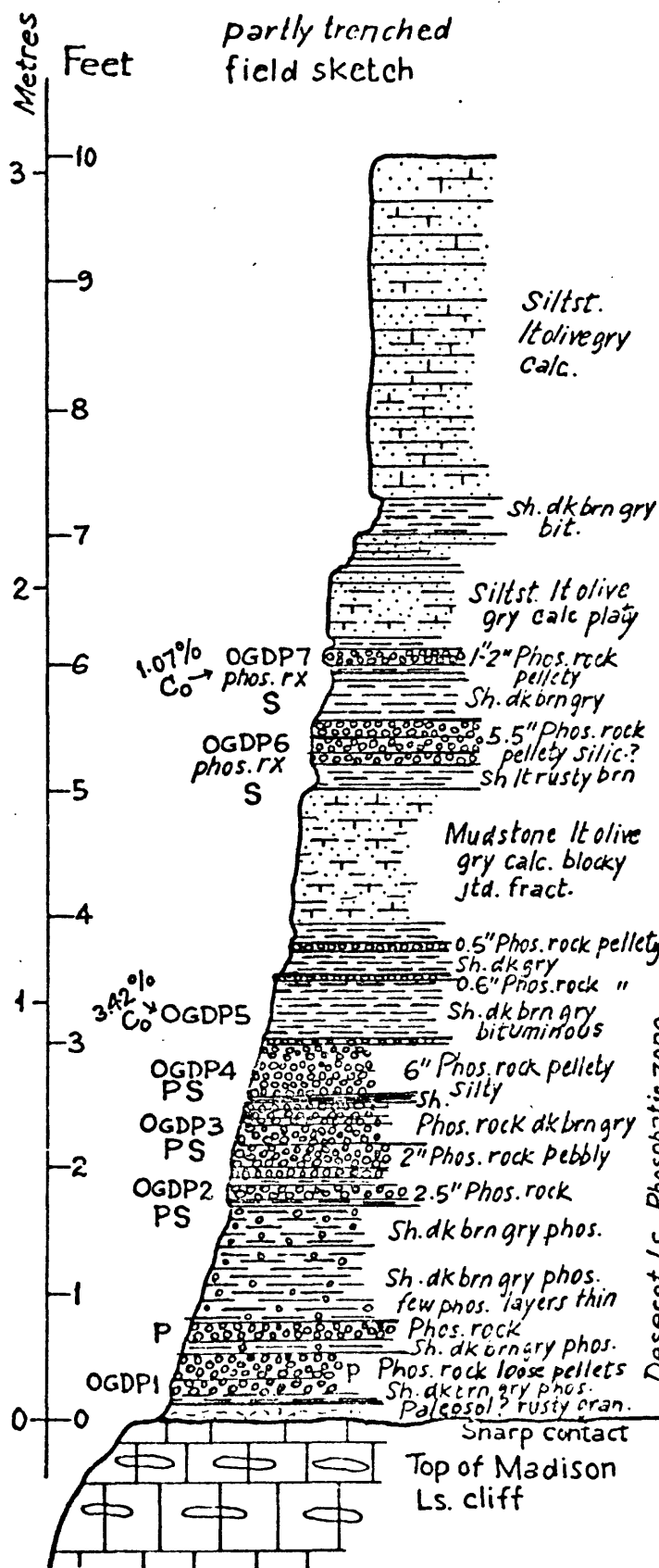


Figure 11.--Detailed measured section of phosphatic zone shown in fig. 10 showing outcrop profile.



OGDEN CANYON SECTION  
bench atop Madison Ls. cliff  
north side of canyon near  
C SW  $\frac{1}{4}$  NW  $\frac{1}{4}$  sec. 16, T. 6 N., R. 1 E.  
Huntsville 1:24000 quad.

Weber Co.  
Wasatch Range

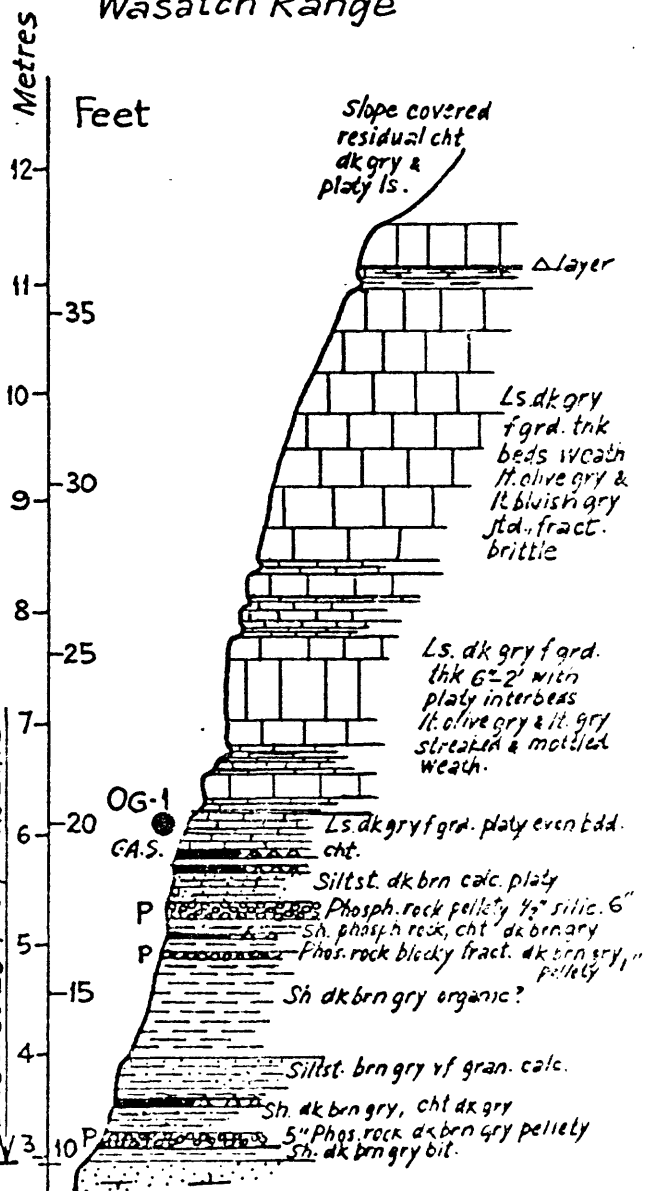


Figure 12.--Lower Deseret phosphatic zone, Ogden Canyon section, Wasatch Range, Utah.

Wheat Grass Canyon Section  
north side of canyon in NE $\frac{1}{4}$  NE $\frac{1}{4}$   
sec. 26, T.7N., R.3E. and SE $\frac{1}{4}$  SE $\frac{1}{4}$   
sec. 23, T.7N., R.3E., Causey Dam  
1:24,000 quadrangle, Weber Co.  
(trenched from 0-9.5 ft.)  
field sketch

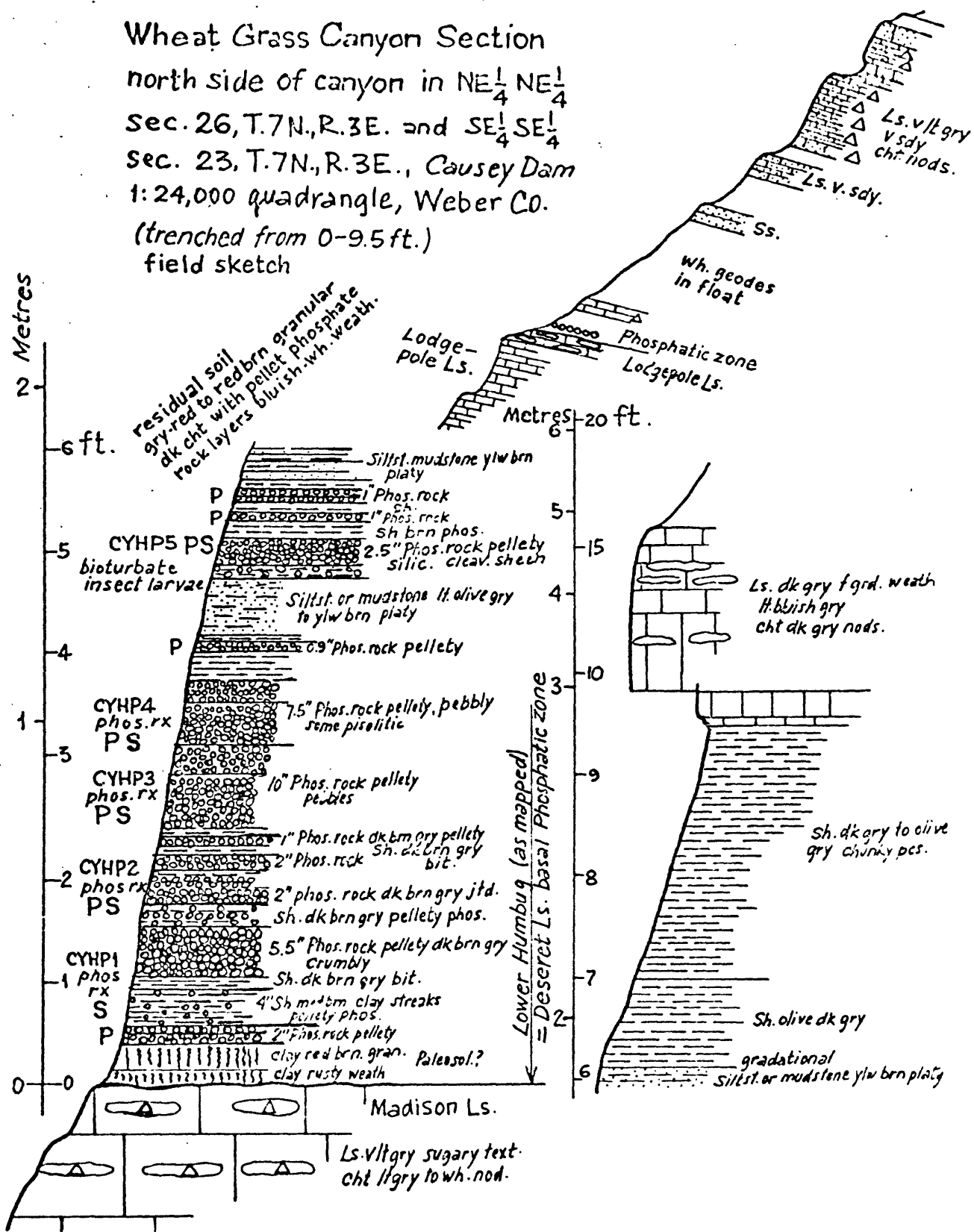


Figure 13.--Lower Deseret phosphatic zone, Wheat Grass Canyon section, Causey Dam area, Utah.

Skunk Spring Section, Confusion Range  
 Chainman Shale, Lower Camp Canyon Member  
 NE  $\frac{1}{4}$  SW  $\frac{1}{4}$  sec. 4, T. 18 S., R. 16 W., Cowboy Pass SW Quad.,

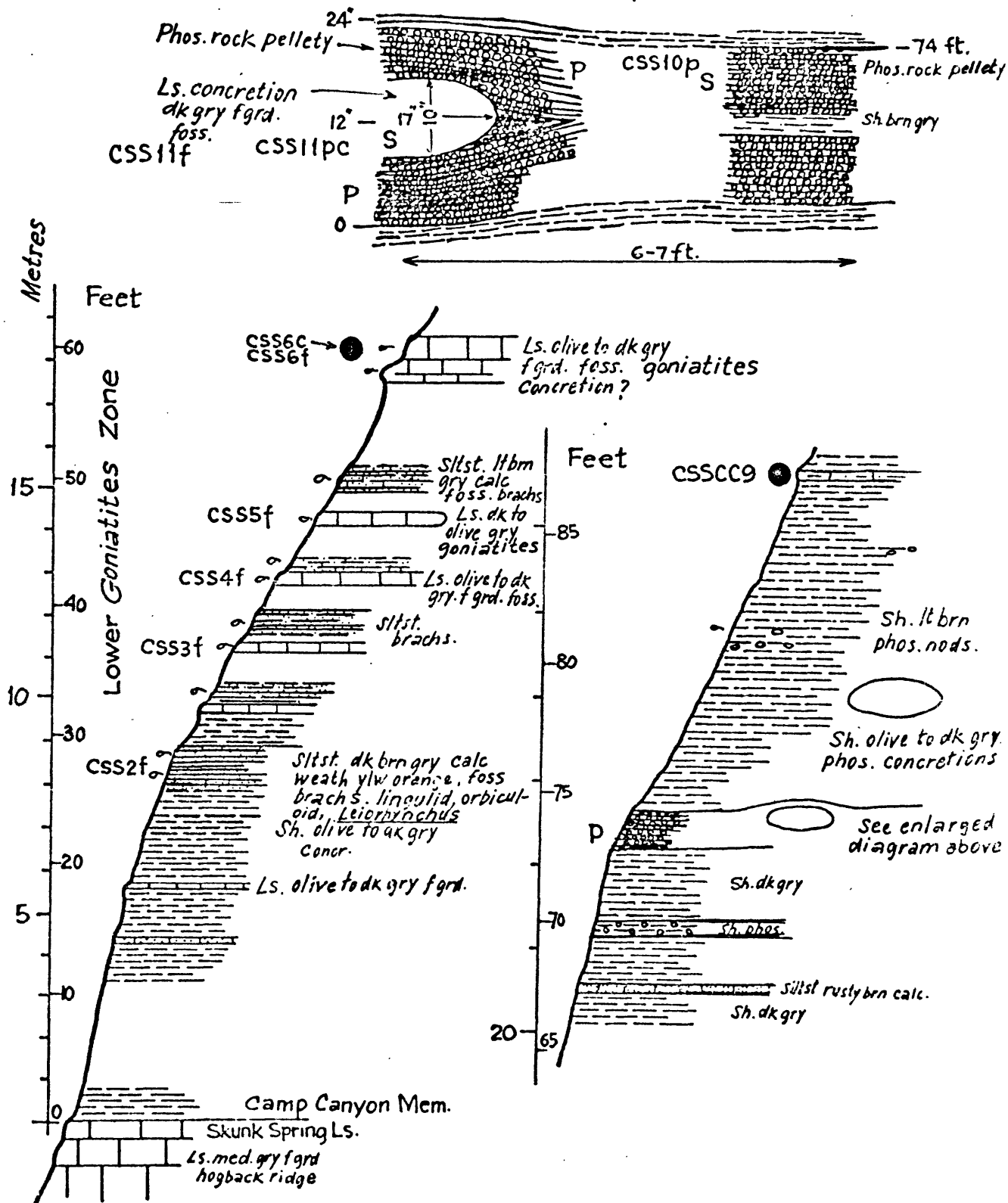


Figure 14.--Phosphate occurrence in lower Goniatites zone of Camp Canyon Member of Chainman Shale, Skunk Spring Canyon section, Confusion Range, Utah.