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Structural Setting and Stratigraphy of Lamproite Occurrences in Woodson and Wilson Counties, Southeast Kansas, USA

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Introduction

The history of the discovery and subsequent identification of lamproite occurrences in Kansas spans more than 120 years. It began in 1879, when B. F. Mudge, the former state geologist of Kansas and professor at the State Agricultural College (now Kansas State University), learned of reports that rich silver and gold ores occurred south of Yates Center in southeastern Kansas (fig. 1). Mudge, together with professor Robert Hay, visited the area in 1879 and noted unusual rocks found nowhere else in the state (Mudge, 1881). Over the years the terminology used to describe the igneous rocks at Silver City Dome, and by implication similar rocks at Rose Dome, has been somewhat confusing. Wagner (1995) describes in detail the use and history of the terminologies used.

In this paper, the terms Silver City Dome and Rose Dome are solely used to refer to the unique topographic features as expressed by their surface morphologies. More recent studies by Cullers et al. (1985) determined the mineralogy of the rocks, and which were subsequently classified as lamproites.

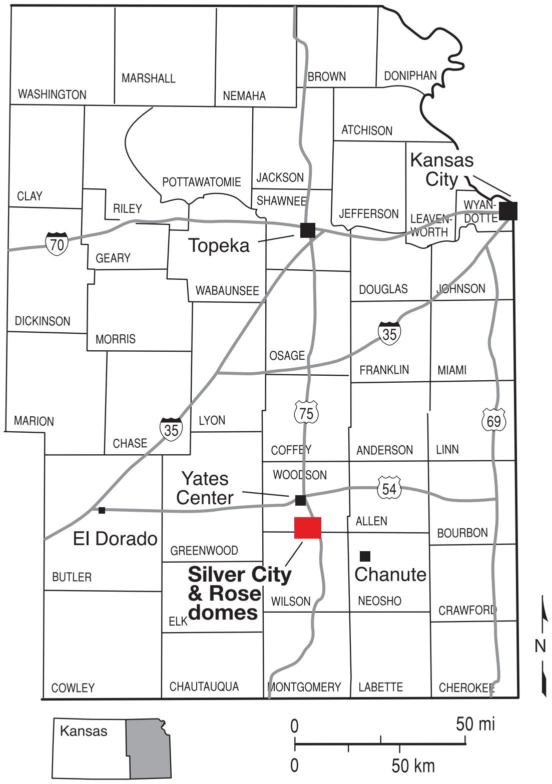


FIGURE 1—Index map showing the location of Silver City and Rose domes south of Yates Center in Woodson and Wilson counties, Kansas.

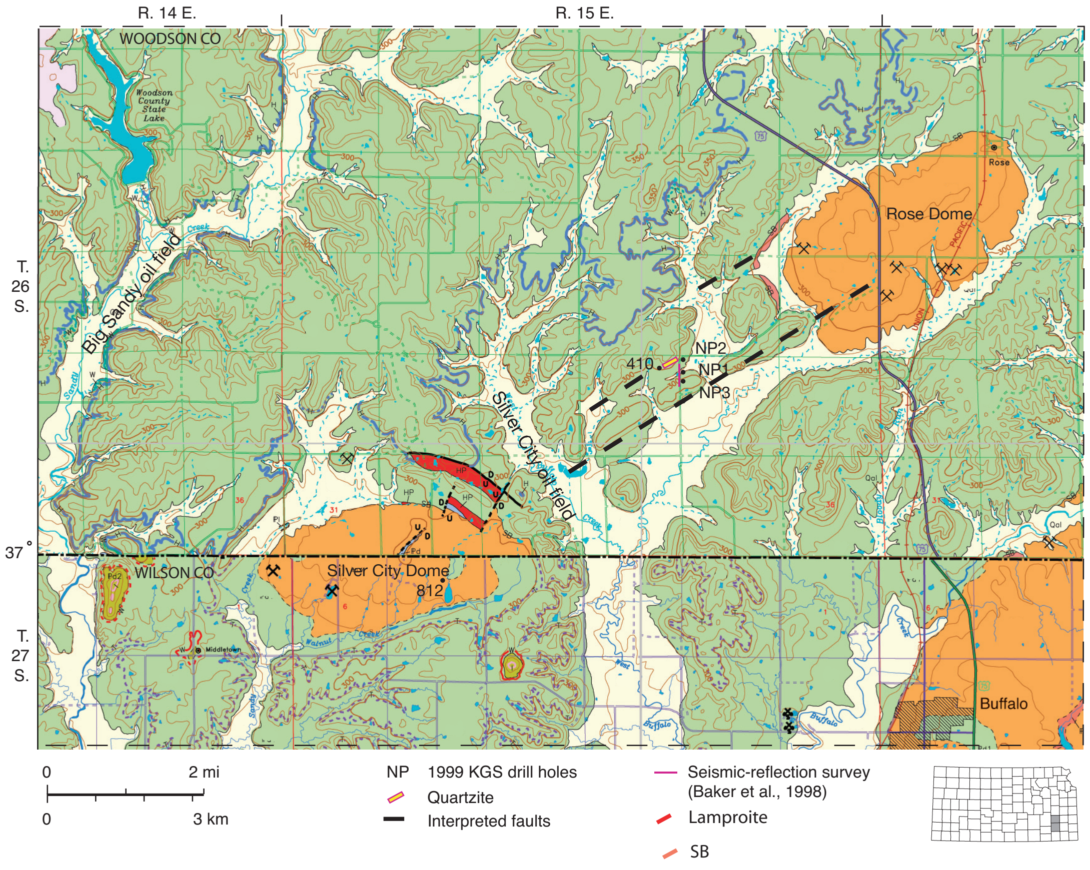
Early History of Lamproite Discoveries

During 1879 reports began to circulate of rich gold and silver occurrences in southern Woodson County near the then-existing settlement of Belmont, about 3 mi (4.8 km) southwest of Yates Center. The reports prompted Professor Mudge, accompanied by Professor Hay, to visit the area in June 1879 (Mudge, 1881). They determined that the area of interest was about 1 mi (1.6 km) long and 1/3 mi (0.6 km) wide, occupying most of the northern part of sec. 32, T. 26 S., R. 15 E. (fig. 2), and that some parts of the Carboniferous (Pennsylvanian) sedimentary units showed evidence of having been metamorphosed. Outside of this small area, the limestones, shales, and sandstones were unaltered. Mudge (1881) attributed the metamorphic changes to "*warm mineral salicious waters*," and noted that the porous sandstones were much more affected than the limestones and shales. He also reported that the clay shales had assumed a granular appearance, interspersed with small flakes of mica. He observed as much as 30 ft (9 m) of this material in several places. Mudge (1881) did not recognize the igneous nature of the rock, even though this material was undoubtedly the olive-brown, soft, weathered lamproite exposed as a sill along the northern perimeter of the area of interest. Mudge (1881) also noted the spectacular exposures of sandstone altered to hard, black quartzite. A number of shallow shafts appeared to have been dug along the northern perimeter of the structure at the contact with the unaltered sedimentary rocks to the north. Rock specimens taken from the shafts, trenches, and exposed ledges by Mudge (1881) were analyzed by Professor Patrick of the State University (University of Kansas) and Professor Failyer of the State Agricultural College (Kansas State University), but no traces of silver or gold were found. Mudge (1881) was surprised to find no lead in the samples, because he made the observation that the rocks were similar in appearance to rocks found in the lead mines in Cherokee County in southeast Kansas.

During the initial period of excitement, followed by the disappointment that no rich silver and gold ores occurred in the area, specimens were sent to Lawrence, Kansas, for examination by a Mr. Savage and Professor Patrick. They noted the unusual nature of some of these rocks, believing that they might be of igneous origin. They contacted Professor Robert Hay to ask his opinion. After examining the specimens, Hay concluded that further field investigations were warranted. During two subsequent field trips to the area, one in the company of Professor Mudge and the other in the company of Professor Middaugh of Humboldt, Kansas, Hay (1883) concluded that at least some of the *dark-blue rock* was a true igneous rock. Hay (1883) also recognized brecciated quartzitic rock, which he called a true metamorphic rock occurring in situ, and slaty shale. In the old shafts and trenches, Hay (1883) also saw plenty of yellow and black, soft, mica-rich material (lamproite), which he referred to as *micaceous dirt.* Professor Hay (1883) was convinced that he had identified true igneous rocks, but he was not able to convince Professor Mudge.

Thirty-four years later Twenhofel (1917) reported on the metamorphic rocks of the area, referring to them as the Silver City quartzites. Twenhofel (1917) shows a hand-drawn figure outlining the Silver City anticline straddling the county line between Wilson and Woodson counties and describes in some detail the unaltered and metamorphosed sedimentary rocks in the area. The paper is mainly devoted to explaining the origin of the earlier discovered quartzites in the northern part of sec. 32, T. 26 S., R. 15 E., and overlapping in sec. 29 to the north (fig. 2), which he refers to as Silver City ridge. On the basis of a thin section examination by A. N. Winchell, Twenhofel (1917) offers a scenario involving brecciation of the more brittle rocks followed by dissolution of the rock by ground water and at a later date, introduction of hot solutions having a significant igneous component that metamorphosed the rocks. Mention also is made of two wells drilled to the top of the Mississippian limestones near the center of the Silver City anticline. In the first well the drillers complained that they encountered rocks that they could not identify, that looked different from rocks found in wells in the vicinity. In the second well to the west, the rocks looked much like those in the first well. According to the drillers records, igneous rocks were not encountered, but slate and mica were found at several intervals. Twenhofel (1917) believed that the slates were just more indurated hard shales and the mica derived from fine-grained sandy shales containing large quantities of mica. Twenhofel (1917) did, however, think it likely, based on data from well logs, that alteration may have affected the sediments beneath the anticline and that the depth at which alteration occurs increases with distance away from Silver City ridge. Because the quartzites contain minerals such as hornblende, Twenhofel (1917) discarded the possibility that cementation of the rocks was caused by cold ground-water solution. He also dismissed the notion that alteration was the result of contact metamorphism, because no igneous rocks were identified that could have provided the heat and liquids necessary to alter the rocks. Thus hot hydrothermal solutions were invoked to explain the metamorphism. The depth from which the solutions came or the origin of them remained a mystery.

Twenhofel (1917) also speculated about a connection between the alteration at Silver City ridge and the granite-



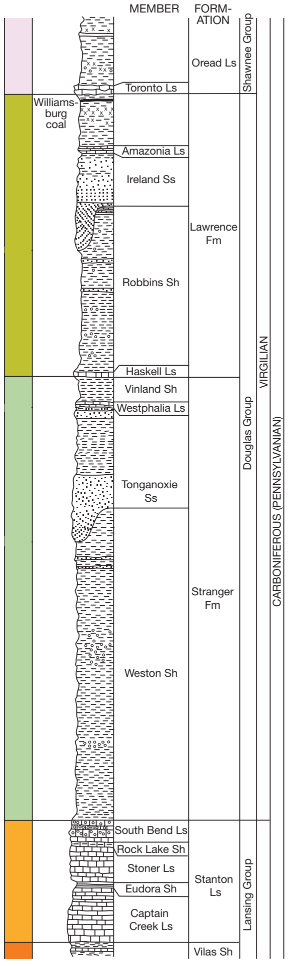


FIGURE 2—Location of Silver City Dome and Rose Dome, Kansas.

porphyry boulders that were found on the surface at Rose Dome, a similar structure about 6 mi (9.6 km) to the northeast. However, he dismissed the idea based on the fact that similar granites encountered in wells in central Kansas are older than the overlying Pennsylvanian rocks. Only if it could be proved that these granites intruded into the Pennsylvanian rocks at Rose Dome could the alteration be linked to such an event.

In a paper written four years later, Twenhofel and Edwards (1921) again reaffirmed their earlier hypothesis that the rocks were metamorphosed by ascending hot solutions of unknown origin. However, in this later paper they state that it is quite probable that igneous rock may be present beneath the Silver City ridge. This idea was based on a paper published by Moore and Haynes (1920), describing the intrusion of basic igneous rock (Bala kimberlite) in Riley County into the flat-lying Pennsylvanian sediments. Twenhofel and Edwards (1921) also note the similar morphology of the landscape near Rose and Silver City and remark on the granite boulders resting on the Pennsylvanian Weston Shale (now Weston Shale Member) at Rose. The authors were particularly interested in finding evidence of shales having been metamorphosed at Rose but were unable to do so. Mr. Hughes, who supervised the drilling of a well at the town of Rose, reported encountering a hard rock in the interval from 1,180 to1,250 ft, which he called a dacite. Twenhofel and Edwards (1921) examined cuttings from the well and decided that the cuttings were mostly hard, cherty limestone from a pre-Pennsylvanian high in the subsurface. During the drilling of the well at the town of Rose, mica also was encountered, but again it was believed to come from the Pennsylvanian sandstones. However, Twenhofel and Edwards (1921) note the northeast-southwest alignment of the fault at Silver City with the boulders at Rose and another fault a few miles north of Silver City. They note that at Silver City, the fault may have a genetic connection with an igneous intrusion. By inference this may then also be the case at Rose and could explain the intrusive origin of the granite boulders.

Twenhofel (1926) finally became convinced that the granite boulders at Rose Dome were evidence of an intrusive event. He based his conclusion on several observations, including a freshly dug highway ditch in which the shale surrounding a boulder was altered over a distance of about 15 inches to a grayish-yellow color with a little silicification of the shale at the contact. Also in 1923, a 1,685-ft (514-m)-deep well was drilled near the granite boulders at the surface. Samples of the lower 400 ft (122 m) were carefully studied and described (table 1) and were reported to contain abundant contact metamorphic minerals, such as diopside, pyroxene, and dark-brown mica (Twenhofel, 1926). Together with the contact metamorphism observed at Silver City, Twenhofel (1926) considered the evidence to be overwhelmingly in favor of granitic intrusive activity at both Silver City and Rose domes. Based on the relatively coarse-grained nature of the granite boulders, Twenhofel (1926) reasoned that the area was overlain by a substantial thickness of sediments at the time of intrusion, placing the age of the intrusion sometime in the Tertiary or earlier.

In early 1924 a well was completed in NE SW sec.19, T. 26 S., R. 16 E. (reported by Twenhofel and Bremer [1928] as sec. 31) on Rose Dome. The well penetrated a black rock containing mica over an interval of about 102 ft (31 m) from 1,153 to 1,254 ft (352–382 m). Samples were examined by Twenhofel and Bremer (1928), who concluded that the rock was a basic igneous rock, probably a peridotite, composed of olivine and brown mica in a fine-grained groundmass. This marks the first time that the mica-rich dark rock was recognized as igneous in origin. Twenhofel and Bremer (1928) also recognized a connection between Rose Dome and Silver City and believed that a large igneous body, similar in composition to the granite porphyry at Rose Dome, underlies the whole area. In their view the peridotite represented late magmatic fluids that were intruded into the overlying sediments.

Knight and Landes (1932) reviewed the knowledge with respect to igneous activity connecting the two domes and summarized their findings on the morphological and structural aspects. Based on this, they proposed that the term laccolith be applied to the domes.

Samples of loose fragments of a hard rock, occurring in an east-west-trending belt several feet wide, along the northern perimeter of Silver City Dome were briefly described by Weidman (1933). He reported that these rocks contained feldspar, quartz, chlorite, epidote, and apatite, and ascribed an igneous origin for them. Weidman (1933) recognized the alteration of Pennsylvanian sandstones to quartzite as a result of hydrothermal alteration by fluids associated with the igneous intrusion. Why Weidman (1933) made a distinction between the intensely contact-metamorphosed rock, which he called igneous rocks, and the less altered rocks, which he referred to as quartzites, in the fault zone along the northern perimeter of the dome, is not clear.

Additional information on the location and occurrence of contact metamorphic rocks at Rose Dome and Silver City Dome was reported by Shaffner (1938).

A geologic map with text describing the geology of the Fredonia quadrangle (Wagner, 1954) is of special interest because it shows a figure and two cross sections detailing the geology together with an interpretation of the origin of the peridotite in the northeastern portion of Silver City Dome. Wagner (1954) was the first to map the surface configuration of the peridotite sill, the fault bounding the peridotite to the north, and the metamorphic aureole around the sill. Wagner (1954) noted that metamorphic effects can be observed in the sedimentary rocks up to a thousand feet away from the peridotite sill. Silicification and chloritization altered sandstones to quartzites, but shales and limestones seem to be much less affected by alteration. Wagner (1954) believed that late acidic solutions associated with the peridotite intrusion were responsible for the metamorphic reactions observed in the sedimentary rocks, but had no effect on the fresh peridotite. Wagner (1954) also mentioned that logs of six wells drilled at Silver City encountered peridotite in the subsurface, similar to that occurring at the surface.

Later publications involving Silver City and Rose domes generally deal with specific geologic aspects of the occurrences such as the mineralogy and petrology, structure, geophysics, stratigraphy, and chemistry. In the following sections these aspects will be discussed individually.

TABLE 1—Description of the cuttings of the lower 400 ft (122 m) from a 1923 drill hole on Rose Dome, possibly the 1 Thad Parsons, detailing the recognition of minerals associated with igneous intrusive activity (Twenhofel, 1926).

1923 T. 26 S., R. 15 E. Elevation: 1,038 ft Total Depth: 1,685 ft Thad Parsons Farm	Feet
White chert with segments of crinoid columns; top of Mississippian limestone	1,298.5
White limestone and green shale, some chert	1,302
Greenish-gray shale; sample contains some white limestone and chert	1,303
White limestone and chert	1,330
Greenish-gray calcareous shale and pale-brown shale; contains particles of the black rocks known to contain dark-brown mica and pyroxene	1,340
White marbelloid limestone	1342
White limestone, white chert, and rock resembling serpentine	1,346
White chert with white limestone. Both limestone and chert contain needle-like crystals of green diopside	1,357
Black shale containing small crystals of pyrite	1,362
White chert and gray limestone; some fragments of black chert (?)	1,369
White chert	1,375
White chert and greenish limestone	1,378
White chert and greenish limestone. Rock contains needle-like crystals of green diopside and black rock composed of dark-brown mica and dark pyroxene	1,380
White chert and grayish limestone, limy shale and black rock containing dark-brown mica and dark pyroxene	1,385
White chert and limestone	1,388
White limestone, calcareous blue shale, and black rock containing dark-brown mica and dark pyroxene	1,392
White chert and limestone with much dark-brown mica, dark pyroxene, needle-like crystals of diopside, and cubes of pyrite	1,410
White limestone and chert with much dark-brown mica, dark pyroxene, and needle-like crystals of green diopside	1,414
White limestone with dark-brown mica and rare crystals of green diopside	1,422
White limestone with a little pyrite, dark-brown mica, and dark pyroxene	1,428
Sample consists very largely of black rock composed of dark-brown mica, dark pyroxene, and some green diopside and pyrite	1,436
White limestone and some chert with much dark-brown mica (5 to 10%), dark pyroxene, and abundant needle-like crystals of green diopside (2 to 3%). Some of the mica is in the form of superimposed hexagonal plates 2 to 3 millimeters (0.08–0.12 inch) in diameter	1,476
White chert and limestone with dark-brown mica and dark pyroxene	1,490
White limestone and chert with some dark pyroxene and much finely divided dark-brown mica. There is also a white fibrous mineral resembling tremolite	1,508
White limestone containing much dark-brown mica and abundant needle-like crystals of green diopside	1,508
Sample largely composed of fine-grained, dense black rock which seems to consist of dark-brown mica and dark pyroxene. Some fragments of green diopside	1,572
White limestone and dense black rock composed of dark pyroxene and dark-brown mica	1,582
White limestone and chert with some black limestone and gray shale	1,590
Gray calcareous shale	1,592
Gray calcareous shale and gray limestone	1,595
Gray limestone with some chert. Some needle-like crystals of green diopside	1,598
Gray limestone and shale	1,600
Weathered chert; light weight and color; composed of chalcedony with some quartz. This probably marks the position of the unconformity at the base of the Mississippian	1,612
Gray limy shale	1,615
White limestone and chert with many particles of black rock composed of dark-brown mica and dark pyroxene	1,618
Fine-grained quartz sandstone; may be replaced limestone	1,624
Dark shale. Brown and white mica and dark pyroxene are present	1,627
Dark limestone rich in argillaceous and siliceous matter; contains some of the black rock composed of dark-brown mica and dark pyroxene	1,631
Gray limestone and much black rock composed of dark-brown mica and dark pyroxene. There is also considerable pyrite	1,639
Gray limestone and gray limy shale, with some particles of black rock like that above	1,643
Sample composed mostly of dark pyroxene and dark-brown mica; some pyrite	1,675
White limestone with dark pyroxene and dark-brown mica; some pyrite	1,675
White limestone with dark pyroxene and dark-brown mica	1,679
Gray silt shale	1,685

Surface Morphology

Silver City and Rose domes have similar morphologic surface expressions. Both domes are ellipsoidal and roughly aligned in a northeast direction (fig. 2). However, the long axis of Silver City Dome trends east-northeast, while the long axis of Rose Dome trends distinctly in a northeasterly direction. Both domes are close to 3 mi (4.8 km) in the long direction and about 2 mi (3.2 km) across, and show crater-like morphologies characterized by a central high surrounded by a "moat" having complete internal drainage. Both domes are tilted and breached to the southwest through which the domes are drained. This is in marked contrast to the general easterly trend of all other drainages in eastern Kansas. Silver City Dome is drained by the Little Walnut Creek, which flows in a southerly direction and empties in the southeast-flowing Verdigris River. Rose Dome is drained by a southwest-flowing tributary of West Buffalo Creek and also empties in the Verdigris River.

The domes are surrounded by low, hummocky hills, quite different from the plains to the east, north, and south of the domes. Higher hills and woodlands adjoin the domes to the west. The domes are a little over 3 mi (4.8 km) apart with the area between them characterized by a series of northeast-trending linear sandstone ridges (fig. 2). Rocks belonging to the upper units of the Lansing Group underlie the central part of the domes (fig. 3). Younger rocks of the Weston Shale Member of the Stranger Formation underlie the "moat" portion of the dome, while still younger rocks of the Stranger Formation underlie the low, hummocky hills surrounding the domes.

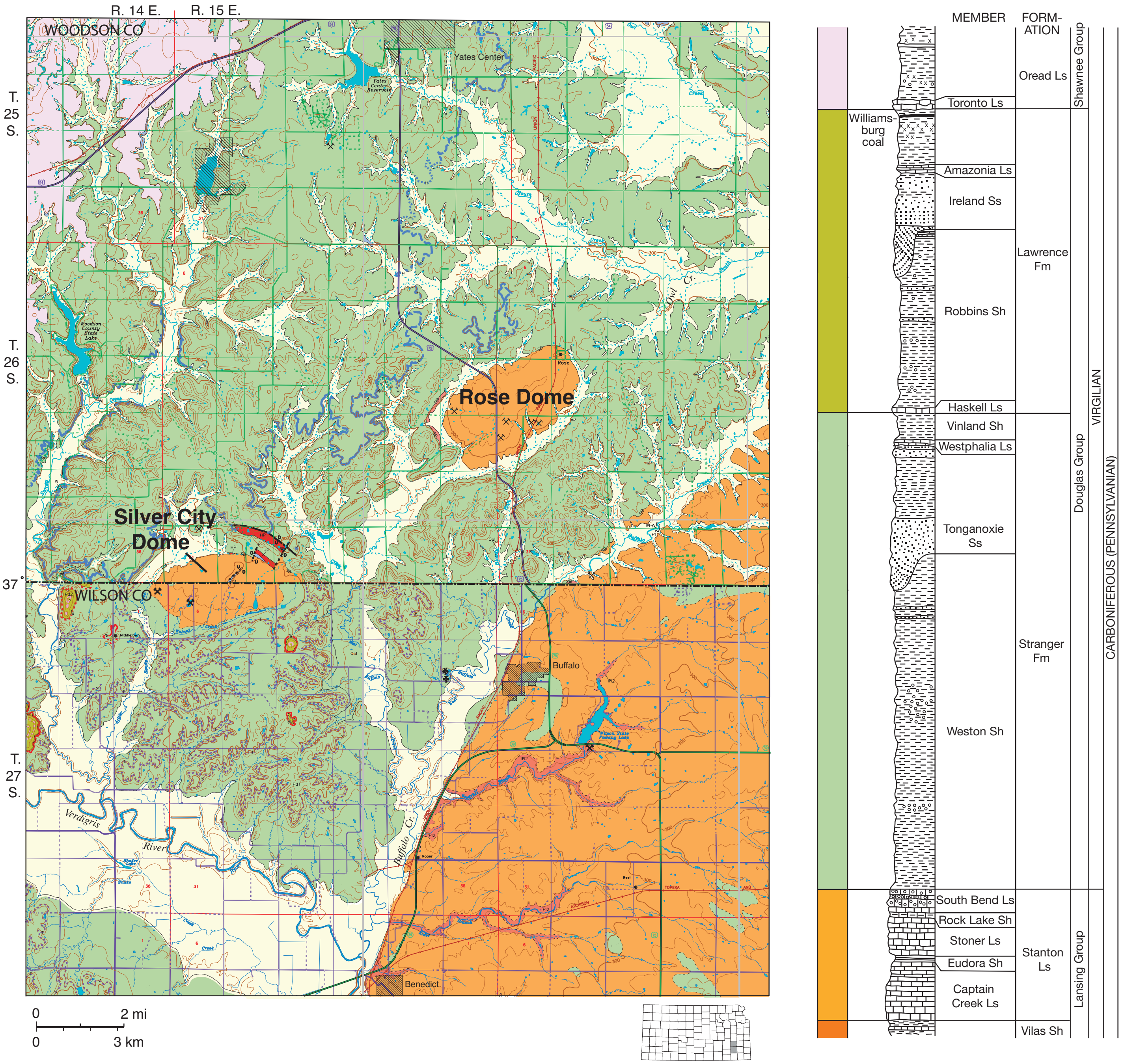


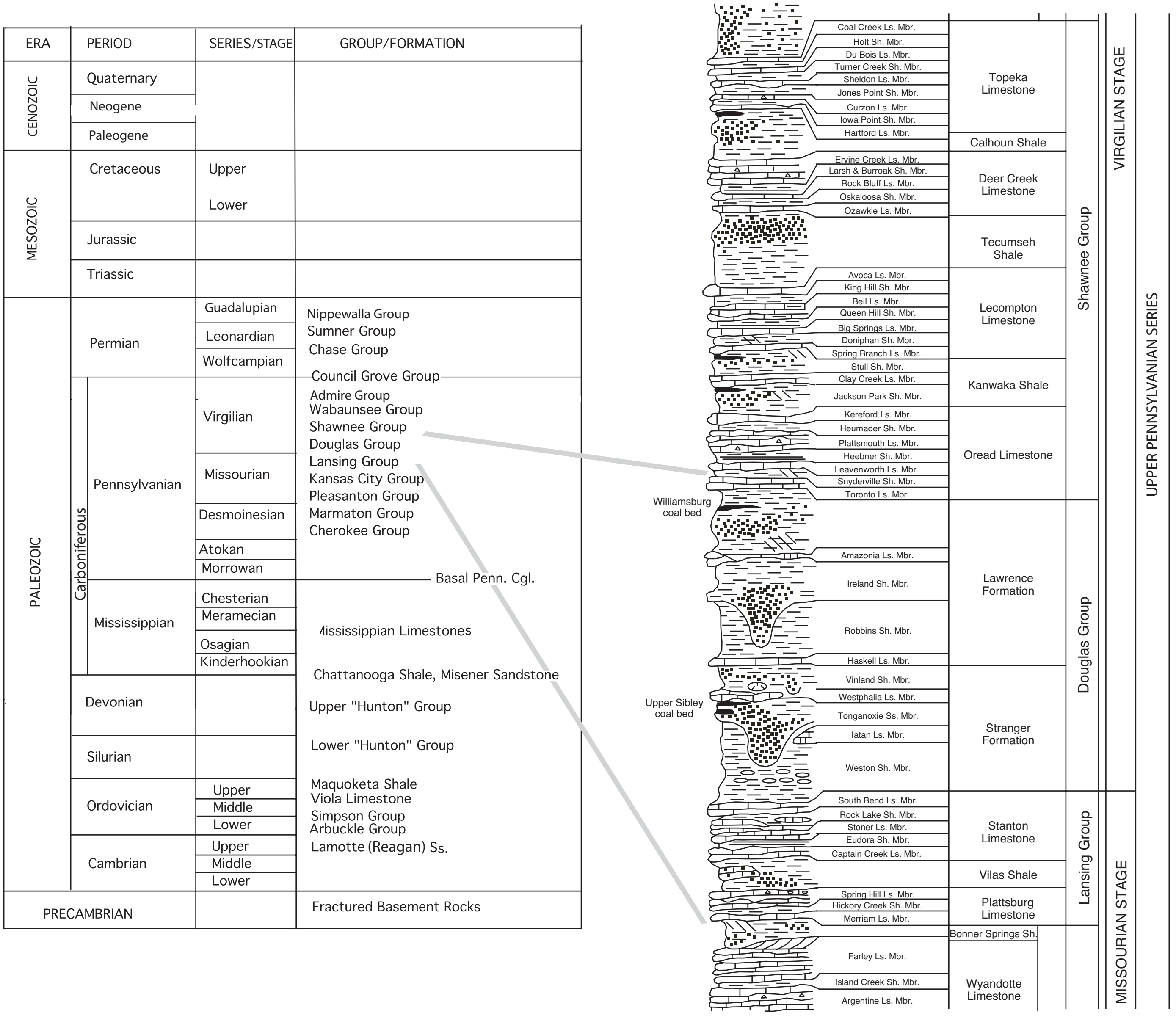
FIGURE 3—Map showing the general geology of Silver City Dome, Rose Dome, and vicinity.

Stratigraphy

Introduction

Rose Dome and the northern half of Silver City Dome are situated in Woodson County. The southern half of Silver City Dome is in Wilson County. The surface rocks in and around the domes belong to the Lansing and Douglas Groups, Virgilian Stage, Pennsylvanian Subsystem, Carboniferous System (fig. 4). Three principal sources of information are available detailing the geology in the two counties. A geologic map of the Fredonia quadrangle was published by Wagner (1954). The map extends north into Woodson County for about 6 mi (9.6 km) and includes all of Silver City Dome. This map also includes an inset geologic map (scale: 4 inches equals 1 mi) of the northern portion of Silver City Dome detailing the occurrence of the igneous rocks and two cross sections showing the author's interpretation of the lamproite rising from depth up along a fault and spreading as sills between the sediments. The map also gives a description of the sedimentary units present in the quadrangle. Wagner (1954) did not include the Weston Shale as a member of the Douglas Group, probably because at the time there was some controversy whether the Weston Shale should be included in the Pedee Group or not. Wagner (2000) published a geologic map of Wilson County, based on the mapping he did in the early 1950's. On this map he recognizes the Weston Shale Member as a member of the Stranger Formation of the Douglas Group. Wagner (2000) also indicates that he is able to map the boundary between the Weston Shale Member and the overlying Tonganoxie Sandstone Member. The base of the Haskell Limestone Member marks the boundary between the Stranger Formation and the overlying Lawrence Formation (Zeller, 1968). On the geologic map of Wilson County, Wagner (2000) mapped this contact throughout the western part of the county.

The northern parts of Silver City Dome and Rose Dome are located in Woodson County. Merriam published a geologic map



Zeller (1968)

FIGURE 4—Classification of rocks exposed in the vicinity of Silver City and Rose domes, Woodson and Wilson counties, Kansas.

of the county in 1998. Because of difficulties associated with defining and recognizing the base of the Tonganoxie in the field, Merriam (1998) does not map individual members of the Stranger Formation (Weston Shale Member and the overlying Tonganoxie Sandstone Member). Merriam (1998) recognizes the top of the Haskell Limestone Member throughout the county, but does not separate the Lawrence Formation as a stratigraphic unit.

Because of the differences in mapping techniques and some uncertainty having to do with recognizing individual members in the field, some apparent ambiguities exist when one compares the two maps. A description of the various stratigraphic units in and around the two domes follows.

Stratigraphy of Surface Rocks

Lansing Group

The oldest surface rocks in the area belong to the Vilas Shale and Stanton Limestone, which are the uppermost two of three formations that make up the Lansing Group (fig. 4). These units consist mostly of limestone with lesser amounts of shale and crop out in the center of both Silver City and Rose domes and in the southeastern part of the map area (fig. 3). Rocks of this group form an escarpment that is easily traced across eastern Kansas. In the study area the limestones commonly form phylloid algal banks or mounds, thus locally increasing the thickness of the individual members (Heckel and Cocke, 1969). However, the total thickness of the formations is not materially affected, because the shales thin over the mounds or banks.

Vilas Shale: The Vilas Shale crops out in the southeastern part of the area in westward-flowing drainages that empty into Buffalo Creek (fig. 3). In the map area the unit attains a thickness of 20–30 ft (6–9 m) and consists of silty and carbonaceous gray to olive-gray shale. A 1-ft (0.3-m)-thick bed of hard medium-gray algal, oolitic limestone occurs about 2 ft (0.6 m) below the top and iron concretions occur near the middle of the formation (Wagner, 1954).

Stanton Limestone: Three limestone and two shale members are recognized in this formation. The formation crops out in the southeastern part of the map area and in the center of both Silver City and Rose domes. The thickness of the formation varies depending on the amount of phylloid algal build-up in the Stoner and Captain Creek Limestone Members, but usually varies between 50–80 ft (15–24 m).

At Silver City Dome the Stoner and South Bend Limestone Members are exposed at the surface (Wagner, 1954). The intervening Rock Lake Shale Member, if present, cannot be mapped. This unit was described by Wagner (1954) as a 2-ft (0.6-m)-thick, yellowish-orange and olive-gray shale, the upper foot being locally very fossiliferous. The Stoner Limestone Member is about 20–25 ft (6–7.6 m) thick and consists of blotchy-looking, light-gray, wavy-bedded, fossiliferous limestone containing many thin shale breaks. The South Bend Limestone Member is a well-bedded, dense to fine-grained gray oolitic limestone reaching a thickness of up to 10 ft (3 m). It crops out in the higher central part of Silver City Dome.

The rocks exposed at or near the surface at Rose Dome are assigned to the two upper members of the Stanton Formation.

Douglas Group

The Douglas Group consists primarily of clastic rocks and is subdivided into the Stranger Formation (lower) and the Lawrence Formation (upper) that underlie most of the map area (fig. 3). The two formations are further subdivided into five clastic units: Weston Shale Member, Tonganoxie Sandstone Member, Vinland Shale Member, Robbins Shale Member, and the Ireland Sandstone Member, separated by three minor limestone members: Westphalia Limestone, Haskell Limestone, and Amazonia Limestone Members. The Iatan Limestone Member (fig. 4) is not present in this area. The Douglas Group reaches a maximum thickness of approximately 400 ft (122 m) in this area (Zeller, 1968). The Weston Shale Member is present at Silver City Dome but not at Rose Dome.

Stranger Formation: Most of this formation is made up of sandstone, siltstone, and shale belonging to the Weston Shale and Tonganoxie Sandstone Members. The other two members, Westphalia Limestone Member and Vinland Shale Member, are thin and of minor importance. The Weston Shale Member crops out throughout the map area as well (as inside Silver City Dome) where it reaches a thickness of about 200 ft (61 m). The shale is medium to dark gray, fissile in certain intervals, and may contain plant fossils and ironstone concretions. Overlying the silty and shaly clastic rocks of the Weston Shale Member are the coarser-grained sandy units of the Tonganoxie Sandstone Member having an average thickness of about 50 ft (15 m). Two distinct lithologic types are described by Wagner (1954). One is a massive, micaceous, channel-filling sandstone that contains a breccia-conglomerate at the base and the other a more rhythmic sequence of alternating micaceous siltstone and claystone. Crossbedded, massive sandstones are well exposed in the map area where they form prominent cliffs or escarpments. The sandstone channels cut into the underlying Weston Shale Member and as low as the top of the underlying Stanton Limestone (Zeller, 1968). The 2–5-ft (0.6–1.5-m)-thick Westphalia Limestone Member is a pale-yellowish-brown algal limestone, which in most places occurs as a composite limestone consisting of two limestone beds separated by a shaly limestone (Wagner, 1954). The whole unit is quite fossiliferous. This member is not easily recognized in the northern part of the map area in Woodson County (Merriam, 1998), but appears to be quite well exposed in the southern part in Wilson County (Wagner, 2000).

The Vinland Shale Member was described by Wagner (1954) as a 6-ft (1.8-m)-thick olive to yellowish-gray silty claystone, the upper foot of which contains large well-preserved pelecypods.

Lawrence Formation: The bottom of the Haskell Limestone Member marks the base of the Lawrence Formation and is made up chiefly of gray shale and sandstone, with minor amounts of red shale belonging to the Robbins Shale and Ireland Sandstone Members. The thickness of the Lawrence Formation is on the order of about 150 ft (46 m), but varies significantly within the map area.

The Haskell Limestone Member at the base of the Lawrence Formation consists of a 2–8-ft (0.6–2.4-m)-thick, medium-gray, fine-grained, fossiliferous limestone. The member occurs widespread throughout the map area, but it may be difficult to distinguish from the Westphalia Limestone Member not far below it.

The Robbins Shale Member consists of olive-gray, silty shale containing beds and lenses of ironstone concretions. In the map area differential erosion has removed more than half from the top of the member, resulting in a greatly reduced thickness of the unit to about 50 ft (15 m) compared to the usual thickness of about 120 ft (37 m).

Siltstone and shale are common in the upper part of the Ireland Sandstone Member, while the lower part is mostly a crossbedded, channel-filling, massive, cliff-forming, very fine grained, orange-gray to brown sandstone. On the geologic map of Wilson County, Wagner (2000) shows the base of the Ireland Sandstone Member, but on the adjoining geologic map of Woodson County, Merriam (1998) does not show the same contact. Because the Ireland Sandstone Member is in large part a crossbedded channel-fill sandstone, the base is difficult to map anywhere in the map area.

The Amazonia Limestone Member is a thin, white to gray, sometimes fossiliferous limestone, that is only exposed in a few places in Wilson and Woodson counties, and is not found in the map area.

Above the Amazonia Limestone Member is an unnamed unit, about 30 ft (9 m) thick, consisting of commonly intermixed sandstone, siltstone, and shale. The sandstones sometimes show ripple marks. The rocks are gray, green, and red colored and contain a thin coal bed near the top that may be correlated with the Williamsburg coal bed better exposed farther to the north.

In the northwestern part of the map area, primarily limestone members belonging to the lower part of the overlying Oread Limestone are exposed at the surface. These rocks rest conformably upon the underlying shales of the Lawrence Formation and do not occur in the subsurface in the map area. For additional information, see Wagner (1954).

Subsurface Stratigraphy

Upper and Middle Pennsylvanian rocks belonging to the lower part of the Lansing Group, and the Kansas City, Pleasanton, Marmaton, and Cherokee Groups are all present in the subsurface (fig. 4). The Plattsburg Limestone, which is the lowest carbonate formation in the Lansing Group, may be as much as 115 ft (35 m) thick as a result of marine limestone banks, but generally is more on the order of 70 ft (21 m) thick in and around the domes. The formation has two members separated by a shale member.

The Kansas City Group is divided into three subgroups that attain an aggregate thickness of about 170 ft (52 m) near the two domes, but increase in thickness in a northeasterly direction. Alternating marine and nonmarine units, similar to those of the overlying units, make up the section. The underlying Pleasanton Group is different in character, consisting of clastic shallow marine and nonmarine sediments having a consistent thickness of about 130 ft (40 m). Yellowish-gray, gray, and black shale dominate the sequence, but sandstone and minor limestone and coal can also be present.

The succession of rocks assigned to the underlying Marmaton Group are similar to those in the Kansas City and Lansing Groups, consisting of alternating limestone and clastic units up to 215 ft (66 m) thick in this area. It should be noted that several of the thin, dark-gray to black, mostly fissile shale units in these groups of rocks, except for the Pleasanton Group, have anomalous concentrations of uranium, making them easily recognizable on electric logs.

Mostly shallow marine and nonmarine clastic units, up to about 370 ft (113 m) thick, make up the succession of rocks assigned to the Cherokee Group. Thin, generally discontinuous limestone units are present. The Cherokee Group is characterized by the occurrence of 12 named coal beds, one of which reaches a thickness of 3.6 ft (1.1 m). Some of these coal beds are discontinuous, but others occur over large areas, extending beyond the borders of Kansas. In the past they have been mined by underground methods, and later as surface mines. However, no mining has taken place in the area under discussion. Examination of cuttings from a drill hole at Silver City Dome shows that Upper and Lower Mississippian rocks, consisting predominantly of limestone and dolomite, are up to about 330 ft (101 m) thick. Minor shale is present in the upper part of the section, but in the lower part of the section the Northview Shale is about 40 ft (12 m) thick. Chert-rich limestone and dolomite characterize the upper 180 ft (55 m), while about 80 ft (24 m) of less cherty dolomitic limestone is present below it and above the Northview Shale. Approximately 13 ft (4 m) of limestone assigned to the Compton (Chouteau) Limestone underlies the Northview Shale. Undifferentiated Lower Mississippian and Upper Devonian rocks totaling about 18 ft (5.5 m) in thickness consist of dark-gray to black shale probably belonging to the Chattanooga Shale. A couple of feet of poorly sorted sandstone assigned to the Misener Sandstone Member usually occur at the base of the Chattanooga Shale in eastern Kansas east of the Nemaha uplift.

Silurian and Ordovician rocks are not present in the area. The Chattanooga Shale unconformably overlies Cambrian–Ordovician dolomites of the Arbuckle Group that are commonly cherty. The thickness of Cambrian–Ordovician rocks in the area is up to about 800 ft (244 m). Below the Arbuckle and directly overlying the uneven basement surface is the Cambrian Lamotte (Reagan) Sandstone. The thickness of the unit is variable and can be as much as 130 ft (40 m). The average thickness is about 40 ft (12 m), and this thickness has been encountered in a drill hole a short distance north of Silver City Dome.

Basement Lithology

No drill holes penetrate the Precambrian basement within the confines of the domes, but north of the domes within about 6 mi (9.6 km), five do reach the basement. Penetration into the basement varies from 1 to 61 ft (0.3–18.6 m) and all encounter granitic rocks, variously described as granite, micrographic granite, and felsite (Berendsen and Blair, 1991). Generally the granite is epizonal and characterized by granophyric to micrographic textures. The rocks are medium grained and consist primarily of perthite (up to 45%), quartz (up to 35%), sodic plagioclase (up to 15%), and biotite (up to 5%), which is often chloritized. Accessory minerals include magnetite, apatite, zircon, and sphene-leucoxene (Bickford et al., 1981). Dennison (1966) also reports similar mineral assemblages, but in addition mentions muscovite, iron oxides, epidote, and calcite. Some of these minerals probably are the result of later secondary alteration or metamorphism. The magnetite content of the granite in individual plutons can vary considerably and reaches concentrations of up to 2 weight percent (Yarger, 1989). Bickford et al. (1981) report that the granites occur as shallow-seated plutons having U-Pb ages of

1,350–1,400 m.y. In the southeastern and extreme northwestern parts of the area, Precambrian sedimentary and metamorphic rocks occur. Their distribution and thickness is quite speculative, but thicknesses of at least 1,500 ft (458 m) have been penetrated by drilling. Berendsen and Blair (1991) believe that these rocks have been preserved in downfaulted blocks or grabens bounded by northwest-trending faults. A similar view was expressed by Sims et al. (1987), who also believe that these rocks are Middle Proterozoic in age. The rocks themselves have undergone low-grade metamorphism and are described as schist, slate, quartzite, and conglomerate. Fragments of igneous rocks, such as granite, rhyolite, and andesite, are commonly found in these rocks.

Regional Structural Geology and Lineaments

Except for the WNW-ESE-trending fault marking the northeastern perimeter of Silver City Dome (fig. 5), no other clearly recognizable surface faults are mapped in the area. The fault at Silver City Dome was recognized by Wagner (1954) while mapping the Fredonia quadrangle. Wagner attached much importance to this fault, because he believed that the fault served as a conduit for bringing igneous rock up to the surface. As part of the Conterminous United States Mineral Assessment Program

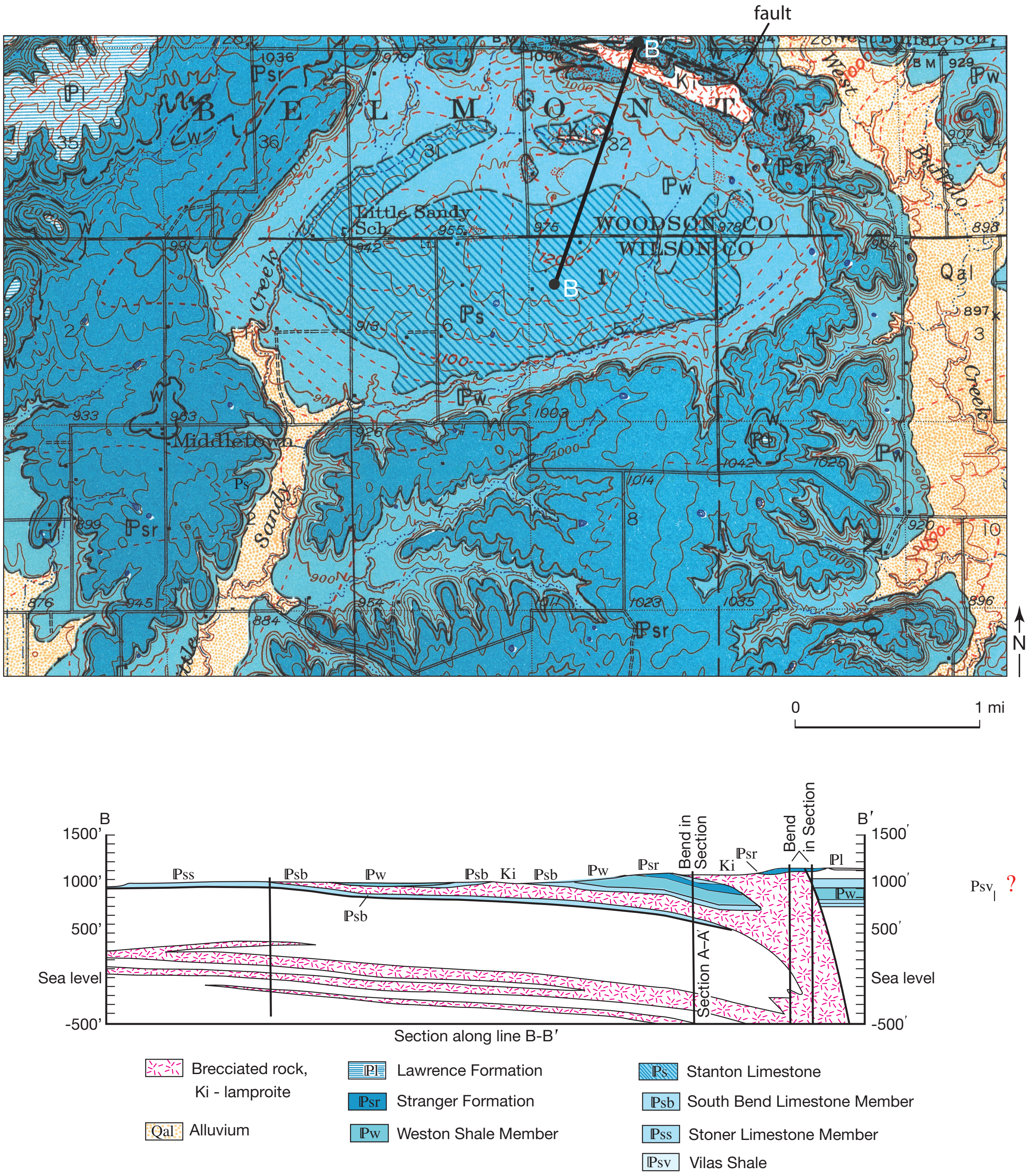


FIGURE 5—Map showing the geology in the immediate vicinity of Silver City Dome and the interpretation by Wagner (1954) in the south-north cross section of the lamproite intruding the sedimentary section.

(CUSMAP), a set of maps of the Joplin 1° x 2° quadrangle (Erickson et al., 1990), which includes Rose and Silver City domes, was published. The maps show several northwest-trending faults both to the northeast and southwest of the two domes. Because of the limited amount of drill-hole data, only the generalized location of the faults is indicated. Northeast- and northwest-trending basement faults also were interpreted to occur in the area by Berendsen and Blair (1991).

About 30 years ago lineament studies received much attention (Basement Tectonics Committee Publication, Inc., 1978), because of widespread interest in trying to understand regional faults and related structures that might influence and affect the design and construction of nuclear reactors, dams, and other large engineering projects. A hierarchical classification of linear features was proposed by O'Leary and Friedman (1978).

Pronounced northeast-trending linear ridges, easily recognizable on topographic maps and underlain by the Tonganoxie Sandstone Member of the Stranger Formation, occur in the area between the two domes (fig. 2). This is the same unit that occurs along the north side of Silver City Dome. Sandstone in contact with the fault that forms the northern boundary of Silver City Dome has been metamorphosed and turned to quartzite. Quartzite was also identified in NE sec. 27, T. 26 S., R. 15 E., giving a strong indication of a northeast-trending fault (fig. 2) being present in the area between the two domes.

Additional information obtained from a variety of sources provided a better understanding of major basement-related structural features in eastern Kansas (Berendsen et al., 1978). The information consisted of rock cuttings and cores from drill holes; various kinds of well logs; aeromagnetic, seismic, and gravity surveys; structure and stratigraphy of the overlying sedimentary units; and the nature of the present-day physiography. The dominant trends of known faults as well as lineaments are northwest and north-northeast. Lineaments showing both trends were recognized in the area of Silver City and Rose domes (Berendsen et al., 1978). A striking north-northeast linear feature is exhibited by the boundary between Pennsylvanian rocks of the Douglas Group and underlying, older rocks of the Lansing Group (fig. 3). Coincident with this boundary is the north-northeast-flowing tributary (Buffalo Creek) of the Verdigris River, which itself follows a strong northwesterly trend. Rose Dome itself is situated along another prominent linear feature defined by the creek draining Rose Dome and the associated linear sandstone ridges and Silver City Dome to the southwest, as well as the northeast-flowing segment of south Owl Creek northeast of Rose Dome (fig. 3).

Drilling

One of the principal reasons to examine more closely the lamproite occurrences at Silver City and Rose domes in Woodson and Wilson counties in the middle 1980's was the unusual and striking similarities in surface morphology exhibited by the domes. Also of special interest was the lamproite sill exposed along the northern perimeter of Silver City Dome. The area was mapped by Wagner (1954), and he interpreted the sill to have ascended along an east-west-trending fault at the northern perimeter of the dome. Because the near-surface lamproite is weathered, this was a good opportunity to get fresh material by drilling into the lamproite close to the fault. Consequently, in 1989 we drilled a 416.4-ft (127-m)-deep hole (figs. 6, 7) close to the fault in the then-existing open-pit mine being exploited by Micro-Lite, LLC. Only 34 ft (10 m) of lamproite was encountered at the top followed by sedimentary rocks of the Pennsylvanian Douglas Group. At the lower contact between the lamproite and the underlying shale, only a thin (less then 1 ft [0.3 m]) contact metamorphic zone was observed. None of the rocks deeper in the drill hole showed any sign of having been affected by the heat of an intruding sill. It was therefore concluded that the sill occurs as an isolated unit within the sedimentary package and that the connection with its "feeder" has been obliterated by post-Cretaceous erosion.

Another interesting aspect is that the sill formerly identified as peridotite is actually a lamproite (Cullers et al., 1985), and is derived from a deep mantle source (Berendsen, 1990). Additional sills or even a centrally located fracture zone along which the lamproite intruded were hypothesized as a result of this drilling.

Early oil exploration in and around Silver City Dome dates from the early 1920's. The Shiltz #1 Lauber (SE NW SW NE, sec. 23, T. 26 S., R. 14 E.) was the discovery well of the Big Sandy oil field (2–2–1926) a couple of miles to the northwest. Development of the Silver City oil field just north of the dome (fig. 2) started with the successful completion (12–13–1946) of the Bisagno Campbell #1 (SE SE SE, sec. 19, T. 26 S., R. 15 E.). Both of these oil fields produce from Pennsylvanian distributary channel sands, known locally as the "Bartlesville." The Silver City oil field formerly terminated near the northeast rim of the dome, but drilling farther to the south in the early 1980's extended production southeastward along the east flank of the dome. Another 26 documented oil-exploration holes were drilled within Silver City Dome (table 2). Lamproite sills were encountered at various depths in all 26 drill holes.

In 1958, the Kansas Geological Survey drilled and partially cored nine holes in sec. 32, T. 26 S., R. 15 E. (1M–7M, fig. 6) to test the extent of the lamproite that was mapped in detail a few years earlier by Wagner (1954). Two were offset holes to get good samples of lamproite. The depth of the holes ranged from 52.5 to 795 ft (16–242 m).

In 1988 the Kansas Geological Survey drilled and partially cored an 812-ft (248-m)-deep hole (SW NW NE, sec 5, T. 27 S., R. 15 E.) on the Ecco Ranch property (Ecco Ranch #1, figs. 2, 8 and table 3). Eight lamproite sills were encountered, ranging in thickness from 1 to 21 ft (0.3–6 m).

To better understand the origin, thickness, and continuity of the sills, the Kansas Geological Survey with the cooperation and financial support of Micro-Lite, LLC, started drilling new core holes at Silver City Dome in 1989. Initially our interest was directed at delineating the surface extent of the exposed sill in the northern part of sec. 32, T. 26 S., R. 15 E., where the lamproite was being mined in a small open-pit operation for use as an industrial mineral in animal-feed applications. In 1989 a 416-ft 4-inches (127-m) core hole (Microlite #1, figs. 6, 7) testing the thickness of the sill exposed in the open pit was completed. In November 1990, using a track-mounted air-powered drill rig, 73 shallow holes were drilled in and around the periphery of the exposed lamproite sill and to the south in sec. 32. Poor recovery of samples due to ground conditions only allowed us to recognize basic rock types, and to accurately delineate the northern boundary of the sill.

In the period from 1991 to 1998, the Kansas Geological Survey drilled 52 holes at Silver City Dome; most of the holes were cored. All holes were drilled in secs. 29, 32, and 33, T. 26 S., R. 15 E., on property owned by Micro-Lite, LLC. The location of the core holes is shown in fig. 6.

At Rose Dome only a limited number of drill holes associated with oil exploration have been completed. The location of the holes and the depths at completion are shown in fig. 9. In 1964 the Kansas Geological Survey completed five drill holes, each less than 100 ft (31 m) deep (see appendix 1) in sec. 13, T. 26 S., R. 15 E. on Rose Dome (fig. 9). The holes were completed towards the center of the dome in an area where the soil mineralogy indicated that lamproite probably occurs close to the surface and where granite boulders were rafted to the surface by the lamproite magma. During exploration for coalbed-methane gas in 2001, a lamproite sill was encountered and brought to the attention of the author. Based upon this information, the Kansas Geological Survey drilled and cored two holes in 2002 in sec. 18, T. 26 S., R. 16 E. (fig. 9).

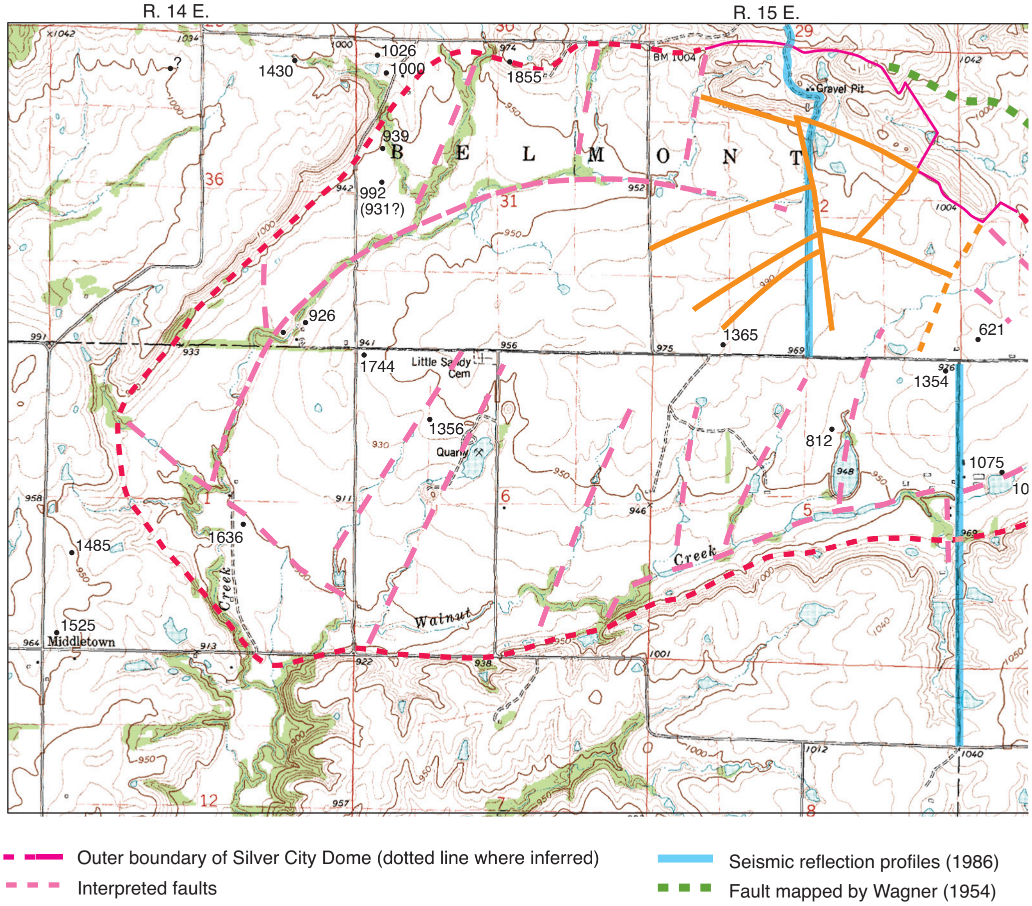


FIGURE 6—Location of holes drilled by the Kansas Geological Survey in the northeastern part of Silver City Dome.

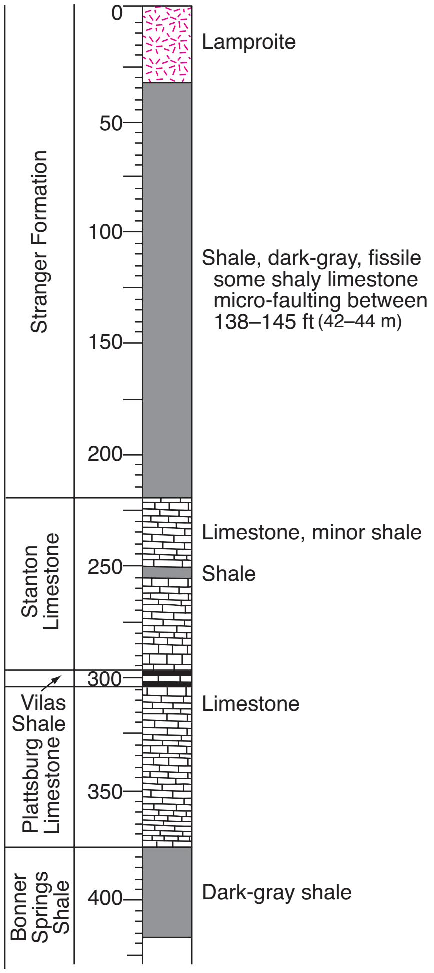


FIGURE 7—Stratigraphic log of drill hole M1.

Lamproite Occurrences

Silver City Dome: The outline of the domes (fig. 2) is based on the premise that no lamproite occurs in the subsurface outside the boundaries. Over a 10-year period this premise has been found to be valid based upon observation and information gained from drilling by oil and gas exploration companies and the Kansas Geological Survey.

At Silver City Dome the majority of drill holes for oil exploration are in sec. 33, T. 26 S., R. 14 E., and in sec. 4, T. 27 S., R. 14 E. (fig. 10, table 2). All drill holes located within the boundary outline of the dome are believed to have encountered lamproite sills. It is sometimes difficult to ascertain whether some drill holes encounter lamproite because the sills are impossible to recognize on electric logs (see section on geophysics) and only a few trained geologists recognize lamproite in cuttings. Lamproite sills are recognized and recorded in geological reports in seven drill holes in the above-named two sections. With one exception the drill holes are completed close to or at the boundary with the Mississippian carbonate rocks at a depth of about 1,500 ft (458 m). The maximum number of sills encountered in one drill hole is seven and the thickness of the sills ranges from a few feet to 72 ft (22 m). The sills cannot be traced for long distances, because they appear to be terminated by numerous faults. Consequently they are found at different elevations in the section, depending on the amount of displacement along a particular fault. The drill holes in which lamproite sills and their thickness can be verified are shown in table 4.

TABLE 2—Drill-hole locations at Silver City Dome.

Drill-hole name	Location	T.D. (ft)
	sec. 36, T. 26 S., R. 14 E.	
Guess No.1	S2 NW	992
Guess No.2	N.A.	931
Guess No.3	NW SW NW	939
	sec. 1, T. 27 S., R. 14 E.	
#1 Clinesmith	NW C SE	1636
	sec. 31, T. 26 S., R. 15 E.	
John Corn	N.A.	1105
1 Corn	NE C	1680
J-Corn	NW C NE	1855
	sec. 32, T. 26 S., R. 15 E.	
#1 George Hill, Sr	SE SW SW	1365
#1 Hill	C SW SE	1340
	sec. 33, T. 26 S., R. 15 E.	
1-33 Eby	SW NE SW	1515
2 Ecco Ranch	SW SE SW	1281
3 Ecco Ranch	SW SW SE	1275
4 Ecco Ranch	NE SE SW	1287
1-K Ecco Ranch	SW SW SW	621
#2 Robbins	SE SE SW	3111
1 Ecco Ranch, Inc	SE SE SW	1291
	sec. 4, T. 27 S., R. 15 E.	
Koch #2	C SW NW	1075
Koch #3	NW SW SE NW	1093
Eby 1-4	Center NE NW	629
Eby 1A-4	1645 ft FNL, 2955 ft FEL	1400
Eby 2-4	330 ft FNL, 2970 ft FEL	1411
Clinesmith 2-4	SW NW NE	1500
Clinesmith 3-4	NW NW NE	1395
	sec. 5, T. 27 S., R. 15 E.	
#1 Young	SE NE NE	1354
	sec. 6, T. 27 S., R. 15 E.	
#1 Bentley	SE NW NW	1356
#1 Hose	NW C	1752

Other drill holes are scattered throughout the dome. Lamproite sills are intersected in the Guess wells in the western part of the dome (fig. 10; tables 2, 4). Thick lamproite sills are also encountered at or near the bottom of three holes drilled in the western part of Silver City Dome (table 4). Other thinner sills may be present but may not have been recognized by the examiner of the drill cuttings. The lower sills were recognized because that core was recovered and oil produced from some of the holes. However, undocumented oral accounts of landowners and drillers confirm that lamproite was encountered in many of the drill holes.

TABLE 3—Drill hole description at Ecco Ranch #1, SW NW NE sec. 5, T. 27 S., R. 15 E.

Depth in ft	**Description**
0–18	casing
18–20	ls
20–30	light-gray ls, buff
30–40	light-gray ls, buff, becoming dark at 33.5 ft
40–50	dark-gray, mottled green-gray ls
49–50	peridotite
50–60	fresh-looking peridotite
60–70	peridotite
70–70 5 inches	peridotite
70 ft 5 inches–74 ft 5 inches	ls, dark-gray
74 ft 5 inches–80 ft	shs, dark-gray or black
80–90	shs, dark-gray
90–100	shs, dark-gray
100–110	shs, dark-gray
110–112 ft 5 inches	dark-gray sh
112 ft 5 inches–120 ft	brown ls (oolitic?) fossiliferous
120–130	~2 ft brown ls ~8 ft medium- to dark-gray ls, all 10 ft fossiliferous
130–140	medium-gray ls with some brown coarsely crystalline chips may have hit thin sh bed at 138.5 ft, fossiliferous
140–150	hitting thin sh beds at 141.0, 141.5, 142.5, 143.0; shales are dark gray; medium-gray ls with brown coarsely crystalline chips; slow drilling at 145 ft (cherty)
149–150	light-brown ls
150–160	light-gray ls; some coarsely crystalline chips
160–170	light-gray ls; tan ls near bottom
173 ft 1 inch	shaly dark-gray
173 ft 5 inches–175	dark-gray ls
175	tan ls
178 ft 1 inch	shaly dark-gray
178–180	dark-gray sh
180–190	dark-gray sh; no mica
190–200	dark-gray sh
200–210	dark-gray sh
210–220	dark-gray sh
220–230	dark-gray sh
230–235	dark-gray sh
241 ft 1 inch	some light-brown to buff ls; crinoid fragments
241 ft 3 inches	light-brown ls fossil fragments
245	dark-gray sh
246 ft 9 inches	light-gray ls
247 ft 4 inches	dark-gray sh
250	dark-gray sh
250–255	dark-gray sh
255	minor mica-peridotite?
256–260	dark-gray sh, fossil fragments
260–263	dark-gray sh; minor light-tan ls at bottom (?)
263–264	dark-gray sh; minor tan to buff ls
264–270	white, crystalline ls; tan to buff ls
270–275	tan to white ls
275–276	dark-gray sh
276–280	medium- to light-gray ls
280–287	medium-gray ls
287–290	light-gray ls
290–297	light-gray to white ls
297–300	tan ls
300–307 ft 5 inches	tan ls
307 ft 5 inches–312 ft 5 inches	medium-gray ls
312 ft 5 inches–313 ft 5 inches	dark-brown ls
313 ft 5 inches–315	peridotite – hard!
315–317 ft 5 inches	peridotite – hard!
317 ft 5 inches–318	black sl or sh; flushed the hole
318–320	brown ls, cherty
320–321	dark-brown ls
321–324 ft 8 inches	dark-gray sh
324 ft 8 inches–325	brown ls
325–326 ft 5 inches	dark-gray sh
326 ft 5 inches	thin, hard surface – ls?
326 ft 5 inches–330	dark-gray sh hit a hard surface at 329.0 ft–light-gray sh
330–334	gray silty sh (Chanute Shale)
334–335	Thayer coal
335–337	Thayer coal
337–339	dark-gray sh
339–350	tan or light-brown ls is cherty [349–350 ft is cherty]
350–353	tan ls, medium-gray ls
353–360	greenish-gray sh
360–363	green-gray sh
363	a little darker
363–370	green-gray sh; minor tan ls
370–374	
374–379	dark-gray sh w/minor gray-green sh
379–380	gray-green sh
380–384 ft 5 inches	dark-gray sh, organics
384 ft 5 inches–386	white to tan ls
386–386 ft 5 inches	dark-gray sh, organics
386 ft 5 inches–390	white to buff ls
390–399	light-tan to buff ls
399–399 ft 7 inches	dark-gray ls cherty; some fossil fragments
399 ft 7 inches–400	light-tan to buff ls; fossil fragments, some chert
400–407	light-tan ls
407–409 ft 5 inches	gray ls, very minor trace of peridotite; dark-green-black mica at 408–408 ft 5 inches
409 ft 5 inches–410	tan ls
410–415	tan to white ls; fossil fragments; some minor chert
415–420	tan ls
420–430	hard, light-tan to light-gray ls, abundant fossil fragments, minor black sh
430–440	light-tan buff ls
440–447	light-tan to white ls
447–450	gray, shaly ls; dark-gray ls
450–452	dark-gray to gray cherty ls
452–454	dark-gray ls
454–455	oolitic ls, medium-gray, argillaceous?
455–457	buff-colored ls
457–460	medium-gray ls cuttings coming up faster—using a thicker mud
460–466	medium-gray ls, argillaceous; few black sh fragments [462-ft hard ledge]

TABLE 3 continued

Depth in ft	**Description**
466–467	dark-gray sh
467–470	medium- to dark-gray ls
470–474	black sh
474	ls; drilling extremely slow
474–480	light-gray ls
480–481	light-gray ls
481–490	green-gray sh, argillaceous
490–491	black sh
491–500	tan ls, minor black sh
500–510	tan to white ls
510–519	tan to light-gray ls
519–520	gray, shaly ls
520–521	gray sh
521–522	gray ls
522–524	soft black sh
524–529	gray ls
529–530	gray, shaly ls
530–534	gray ls with gray sh
534–538	gray sh, few black sh fragments
538–540	soft, light-gray ls
540–550	light-gray to white ls; soft, few hard ledges near bottom (549 ft)
550–556	light-gray ls to 556 ft
556–558	darker-gray, shaly ls
558–560	dark-gray sh
560–561	dark-gray to lighter-gray sh
561–562	dark-gray sh
562–570	ls, light-gray Drum?; medium-gray ls with dark-gray sh
570–576	light-gray ls becoming darker towards the bottom
576–577	light-gray ls becoming darker towards the bottom
577–580	dark-brown grainy soft stuff (might be peridotite)
580–582	dark-brown stuff; peridotite
582–589	light-gray ls turning to dark-gray ls
589–590 ft 5 inches	black sh
590 ft 5 inches–591	ls, dark-gray
591–600	dark-gray sh (hit thin ls at 594 ft; dark-gray ls)
600–606	dark-gray and black sh
606–610	dark-gray and black sh
610–620	dark-gray and black sh
620–630	dark-gray sh
630–640	dark-gray sh
640–647	dark-gray sh
647–650	light-gray sh
650–660	dark-gray sh
660–669	dark-gray sh
669–670	light-gray to white cherty ls
670–675	
675–677	light-gray sh
677–680	gray to black sh
680–682	sh?
682–683	light bed
683–684	sh
684–690	light-gray sh, ls, gray sh
690–691	gray sh
691–692	hard-peridotite(?)
692–698	gray, dark-gray, black sh
698–700	gray ls
700–710	gray ls
710–711	gray ls
711–715	black sh, gray to bottom
715–716	gray ls
716–720	gray sh
720–721	gray sh
721–726	silty gray sh
726–729	light-gray siltstone
729–730	black sh
730–734 ft 5 inches	dark-gray sh, green-blue siltstone veinlets
734 ft 5 inches	peridotite chips
734 ft 5 inches–738	peridotite
738–740	peridotite
740–743	peridotite
743–744	white marble, veined
744–745 ft 5 inches	peridotite
745 ft 5 inches–746 ft 5 inches	green altered slate with peridotite, minor black sh, peridotite punky
746 ft 5 inches–749	blue-green slate, no peridotite
749–750	reddish-brown sh
750–751	reddish-brown sh
751–756	gray sh
756–758	dark-gray sh
758–758 ft 5 inches	minor peridotite, some blue-green slate
758 ft 5 inches–760	gray sh, minor blue-green slate
760–770	blue-green slate, minor brown peridotite, gray sh, easy drilling from 764 ft, darker gray
769–770	lighter gray-brown
770–770 ft 5 inches	brown sh
770 ft 5 inches–771	green slate
771–778 ft 5 inches	peridotite
778 ft 5 inches–778 ft 8 inches	more gray-green sh
778 ft 8 inches–779	black sh
779–781	blue-green slate
781–790	alternating green slate and lamproite
798	start getting in mostly lamproite
812	stopped drilling

Even though several of the drill holes bottom out at or near the Mississippian contact (at about 1,500 ft [458 m]), most lamproite sills occur at depths shallower than 900 ft (275 m) in rocks of the Marmaton Group (fig. 4).

The maximum thickness of any sill is on the order of 100 ft (31 m), and generally the thickest sills occur nearer to the present-day surface. Numerous thin sills, from 1 to 20 ft (0.3–6 m) thick, occur throughout the section. There are some uncertainties as to the actual thickness of some sills because of contamination of lamproite magma with country rock, as well as the thickness of the contact metamorphic zone at the boundary between a sill and the country rock.

Based on information from five drill holes, Wagner (1967) made the observation that lamproite sills only occur within the confines of the dome. In his cross section (fig.11), Wagner (1967) interprets the thick lower lamproite sill to be continuous over an east-west distance of 2 mi (3.2 km) between the Hase No.1 to the west and the Young No. 1 to the east (tables 2, 4). Other sills are of more limited extent, and all sills are shown to pinch out

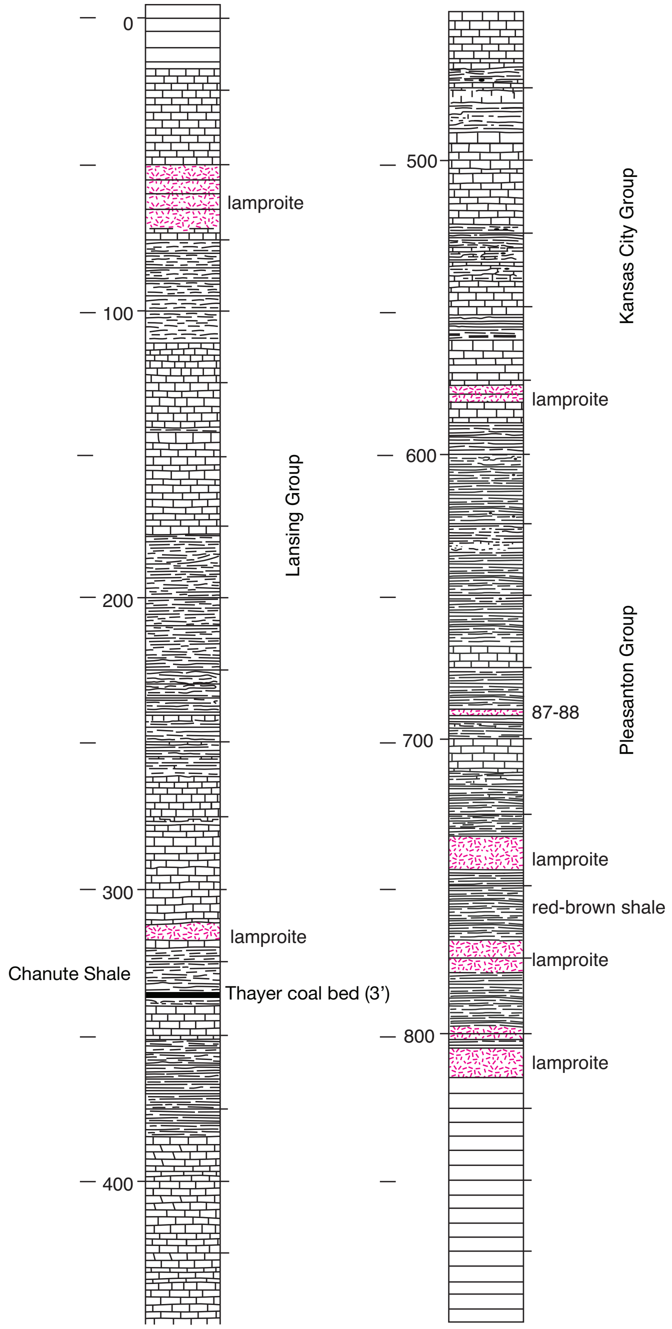


FIGURE 8—Stratigraphic log of the #1 Ecco Ranch drill hole, Silver City Dome.

with distance away from the drill hole in which they are found. In 1988 the Kansas Geological Survey completed an 812-ft (248-m) hole on the Ecco Ranch property in sec. 5, T. 27 S., R. 15 E. (figs. 8, 10, tables 3, 5) and found eight sills ranging in thickness from 1 to 22 ft (0.3–7 m). No correlation is apparent between lamproite sills occurring in this drill hole and the Young No. 1 drill hole 1/4 mi (0.4 km) to the east. It also is difficult to find a good correlation between sills listed in the drill holes in table 4, even though there are some indications that the higher sills are present in several drill holes at approximately the same depth. If they can be correlated, the sills must indeed pinch and swell. However, as we shall see in the structure section, the idea that the sills pinch and swell appreciably is not favored.

To help formulate ideas about the genesis of the domes, it is important to understand the physical and chemical nature of the sills. As a result, the Kansas Geological Survey, with financial support of Micro-Lite LLC, drilled 52 holes during the period from 1991 to 1998. The majority of the holes were drilled in sec. 32, T. 26 S., R. 15 E., except for a few that were spotted in the extreme southern part of sec. 29 to the north. The depth of the drill holes varies from a few tens of feet to more than 400 ft (122 m). Descriptions of the rocks encountered in the drill holes and graphical representations in the form of strip logs are given in appendices 1–5.

The first drill hole M 1 (fig. 7), spotted in 1989 in the existing open pit close to the fault separating the sill from the metamorphosed siltstone and sandstone of the Stranger Formation to the north, reached a depth of 416 ft 4 inches (127 m). The drill hole was spotted here to test the hypothesis forwarded by Wagner (1967) that the lamproite ascended along the fault from depth and spread out laterally between the shales and siltstones of the Weston Shale and the Tonganoxie Sandstone Members of the Stranger Formation (fig. 4). Only 32 ft (10 m) of lamproite was encountered, followed by 190 ft (58 m) of shale, siltstone, and sandstone of the Stranger Formation, 76 ft (23 m) of limestone and dolomite belonging to the Stanton Limestone, 9 ft (3 m) of underlying shale and limestone assigned to the Vilas Shale, 68 ft (21 m) of Plattsburg Limestone, and 42 ft (13 m) of Bonner Springs Shale.

The data obtained from this drill hole were not unexpected and pointed to the need to get more information on the distribution and nature of this sill and possible other ones. In 1991, 16 holes (fig. 6, and see appendix 1 for descriptions and graphic representations of drill holes) were drilled in and around the then-existing open-pit mine in the northern part of sec. 32, T. 26 S., R. 15 E. The depth of the drill holes varied from 26 ft to 188 ft (8–57 m). The main purpose was to determine the areal extent and thickness of the sill exposed at the surface. As a result of this activity, the northern boundary of the sill was accurately located and, with reasonable certainty, determined to be a fault. The fault dips steeply to the north (fig. 12) but is believed to be more vertical at greater depths. The drilling showed that the lamproite sill exposed in the open pit (fig. 13) extends for about half a mile (0.8 km) in a east-southeasterly direction (fig. 14). A maximum thickness of 113 ft (34 m) of lamproite was encountered in drill hole 3–91 (fig. 6, see appendix 1). The thickness of the lamproite sill in the open pit is believed to be the same, but could not be determined accurately because the amount of lamproite removed by mining can only be estimated. The sill dips at an average angle of about 5 ° to the northeast and pinches out to the south along the side of the low hill south of the open pit.

In the west-central part of sec. 32, Wagner (1967) shows two minor lamproite occurrences at the surface near drill hole 2–92 (fig. 5). During the 1992 drilling season, another 12 holes were drilled to document this occurrence (appendix 2), except for drill hole 1–92, which was drilled along the northern perimeter of the dome (fig. 6). At this location very hard quartzite crops out at the surface, but earlier geologic field investigations indicated that the quartzite may be underlain by lamproite. The results of the drill hole show that quartzite and slate occur to a depth of 49 ft (15 m), below which 8.4 ft (2.6 m) of partially contaminated lamproite is present. Later mining operations showed that the quartzite and slate formed a large raft of metamorphosed sedimentary material within the lamproite sill. Eleven more holes were spotted in locations that gave potential information about the subsurface

TABLE 4—Lamproite sills in commercially drilled holes at Silver City Dome.

Drill hole name	Location	Depth (ft)	Thickness (ft)	T.D. (ft)
Eby 1–4	sec. 4, T. 27 S., R. 15 E. center NE NW	325–370 420–424	45 4	629
Eby 1A–4	sec. 4, T. 27 S., R. 15 E. 1645 ft FNL, 2,955 ft FEL	318–390 400–440? 612–628 731–736 795–810	72 40 16 5 15	1400
Eby 2–4	sec. 4, T. 27 S., R. 15 E. 330 ft FNL, 2,970 ft FEL	302–370 410–412 476–488 610–618 730–760	68 2? 12 8 30	1411
Clinesmith 2–4	sec. 4, T. 27 S., R. 15 E. SW NW NE; 990 ft FNL, 2,310 ft FEL	620–638?	18	1500
Clinesmith 3–4	sec. 4, T. 27 S., R. 15 E. NW NW NE 330 ft FNL, 2,310 ft FEL	716–756 764–770	40 6	1395
Eby 1–33	sec. 33, T. 26 S., R. 15 E. SW NE SW	475–490? 886–934	15 48	1515
1 Ecco Ranch, Inc	sec. 33, T. 26 S., R. 15 E. SE SE SW	374–400 428–432 458–484 520–531 602–616 755–786	26 4 26 11 14 31	1291
Guess No.1	sec. 31, T. 26 S., R. 15 E. S2 NW	884-992	108	992
Guess No.2	sec. 31, T.26S., R.15E.	824–920	96	931
Guess No.3	sec. 31, T. 26 S., R. 15 E. NW SW NW	870–939	69	939
Hase No. 1	sec. 6, T. 27 S., R. 15 E. NW NW NW	915–1105	190	1744
Bentley No. 1	sec. 6, T. 27 S., R. 15 E. SE corner NW NW	910–1060 1142–1155	150 13	1356
Young No. 1	sec. 5, T. 27 S., R. 15 E. NE NE	298–350 620–644 805–820 1028–1056	52 24 15 28	1354

extension of the surface occurrence of lamproite mapped by Wagner (1967). Cross section B–B´ (fig. 15) shows that the lamproite occurring at the surface can be traced northward in drill holes 2–92, 3–92, 4–92, and 5–92 (fig. 13). The sill attains a thickness of 41–47 ft (12.5–14 m) and dips in a northerly direction. Southward from drill hole 2–92, in drill holes 9–92 and 10–92, a lamproite sill of similar thickness is intersected. If this is a continuation of the same sill, the dip on the sill reversed.

East of drill hole 2–92, in drill holes 6–92 and 7–92 (fig. 6), a similar, but somewhat thicker (50 and 57 ft, respectively [15 and 17 m]) lamproite sill is encountered (fig. 16). Whether this is the same sill encountered in the previous drill holes is difficult to know. It is also difficult to know if the sill in these holes dips to the north or to the south. The 5-ft (1.5-m)-thick lamproite sill encountered in drill hole 8–92 (see appendix 2) is probably the same northward-dipping sill as seen in drill holes 2–92 through 5–92 (fig. 6). It is quite possible that the sill thickens slightly to the east.

Drill hole 11–92 is due south from drill hole 7–92 (fig. 6). The thickness of the lamproite sill is 53 ft (16 m), which is

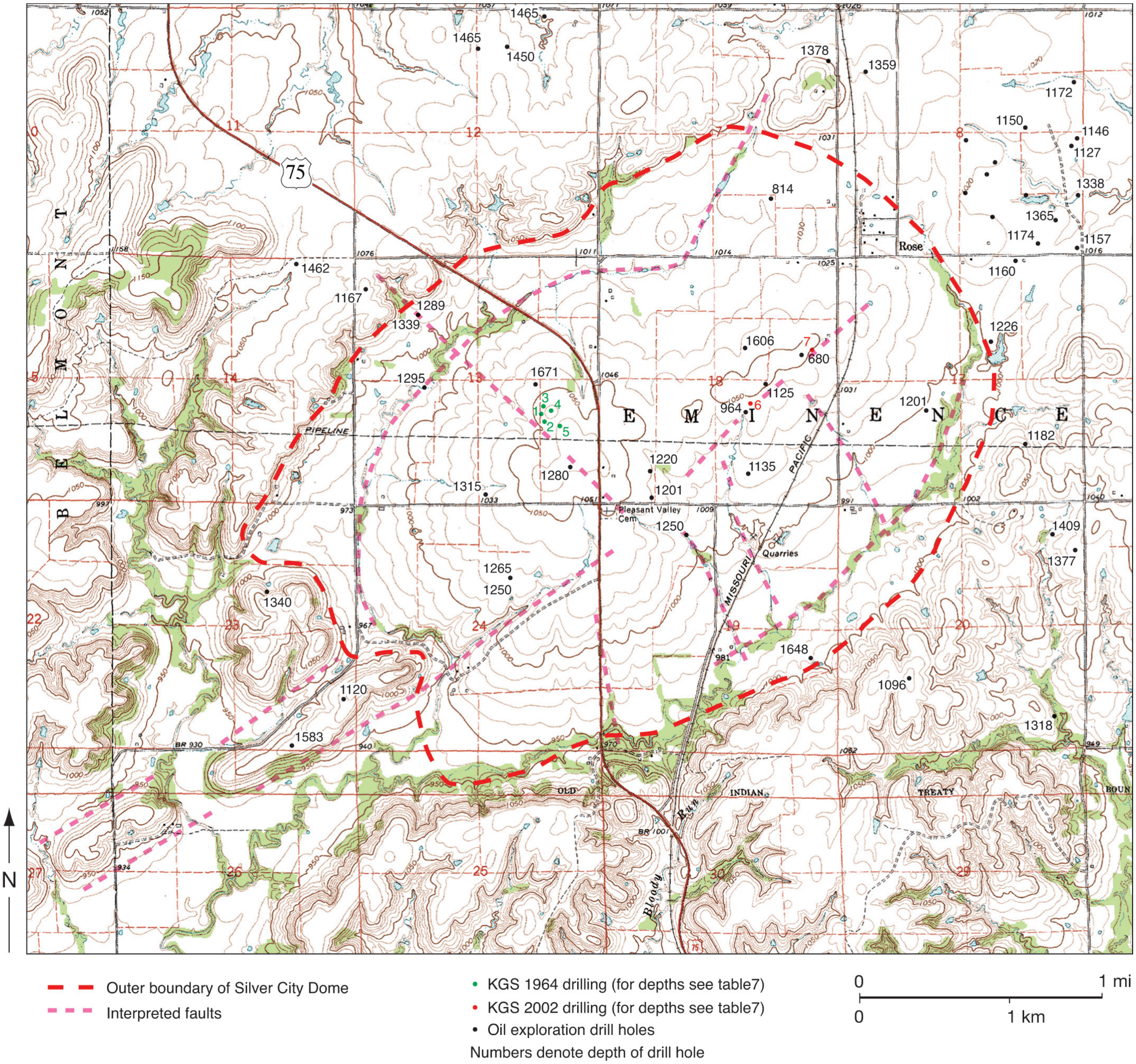


FIGURE 9—Rose Dome. The location of drill holes; major interpreted structures as well as the outline of the dome are shown.

similar in thickness to the sill in drill hole 7–92 (see appendix 2). The thickness of the lamproite sill in drill hole 12–92 is slightly thicker than the sill in drill hole 7–92 to the southwest. This may be the same sill and represent a thickening of the sill to the east (fig. 16).

During the 1995 drilling season, six holes were completed (fig. 6). The drill-hole locations were selected to provide additional information on the extent of the sills previously discovered. Drill hole 1–95 is located a few hundred feet south of drill-hole location 1–92 (fig. 6). It was drilled to evaluate the thickness of the lamproite sill just south of the northern boundary fault. Only 3 ft (0.9 m) of metamorphosed shale and sandstone overlie 79 ft (24 m) of lamproite at this location (see appendix 3). Drill hole 2–95 was spotted due south of drill hole 11–92 (fig. 6). At this location 53 ft (16 m) of lamproite is overlain by 64 ft (20 m) of limestone (see appendix 3). Hole 2–95 (fig. 6) was drilled to a depth of 189 ft (58 m), but no lamproite was encountered. To further define the limit of the lamproite sill encountered in drill hole 11–92, drill hole 6–95 was spotted halfway between drill holes 11–92 and 2–95 (fig. 6). The hole was drilled to a depth of 76 ft (23 m) and again no lamproite was encountered (see appendix 3). The location of drill hole 3–95 was deliberately selected to check the northern extension of the sill encountered in drill holes 2–92 through 5–92 to the south (fig. 6). Based upon the dip of the lamproite sill found in those holes, lamproite in drill hole 3–95 should have been encountered at a depth below 70 ft (21 m; fig. 17). The hole was drilled to a depth of 350 ft (107 m) and no lamproite was found (see appendix 4). Interestingly, numerous high-angle healed fractures in the shale are common in the interval between 38 and 178 ft (12–54 m). Between 178 to 197 ft (54–60 m), at the contact of the shale and the underlying limestone, igneous material resembling lamproite, but badly contaminated with shale and limestone, occurs. Below 197 ft (60 m), unaltered limestone and, towards the bottom of the hole, gray shale are present.

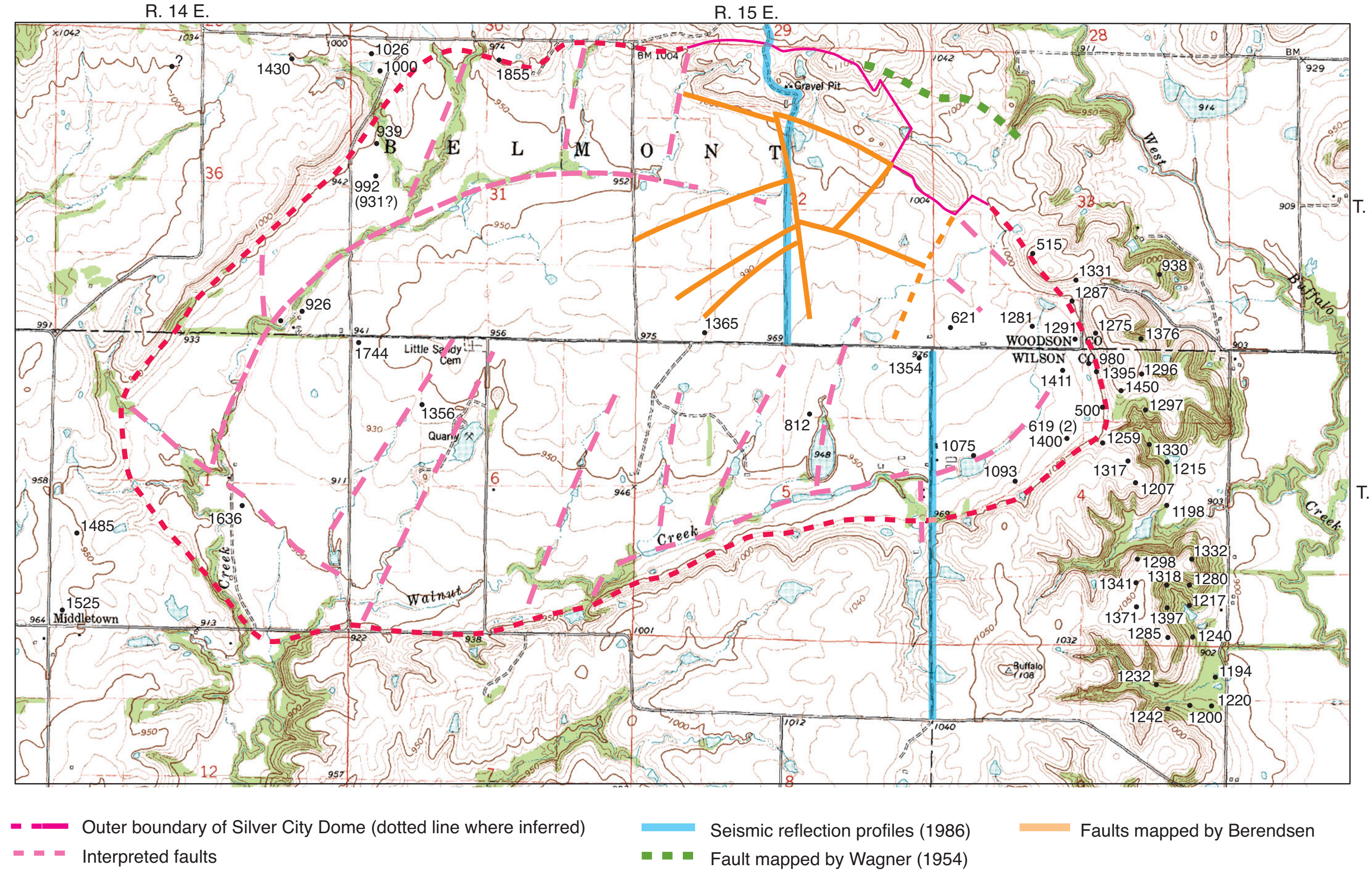


FIGURE 10—Silver City Dome. Shown are the location of drill holes in and around the dome as well as interpreted and mapped faults and the location of a seismic line.

Drill hole 4–95 was spotted near what is believed to be the northeastern limit of the lamproite sill extending from the existing open pit eastward (fig. 6). Below a shallow soil cover, lamproite is present to a depth of 31 ft (9 m; see appendix 3).

Drill hole 5–95 is located half-way between drill holes 2–92 and 9–92 (fig. 6). The drill hole was spotted here to establish whether the north-dipping sill in drill hole 2–92 is connected to the southward-dipping sill present in drill hole 9–92 (fig.15). The sill seems to continue but reverse dip in this area.

During the 1997 drilling season another 12 holes were drilled (fig. 6). Because drill hole 4–95 still intersected lamproite, drill hole 1–97 was spotted about 500 ft (153 m) to the southeast (fig. 6). The hole was drilled to a depth of 178 ft (54 m) and intersected 164 ft (50 m) of unaltered shale underlain by limestone (see appendix 4). Hole 2–97 (fig. 6) was drilled to check on a possible eastward extension of the sill encountered in drill hole 12–92, where 63 ft (19 m) of lamproite was encountered at a depth of 36 ft (11 m; see appendix 2). In drill hole 2–97, 44 ft (13 m) of lamproite occurs under a very shallow soil cover and is underlain by metamorphosed hard black shale containing many fractures whose surfaces are coated with pyrite. Slightly less metamorphosed shale occurs in the interval between 82–102 ft (25–31 m). However, some lamproite occurs as inclusions within the shale. From 102 to 123 ft (31–38 m), the rock consists of a mixture of metamorphosed, brecciated limestone, shale, and lamproitic material. The lower contact with fresh limestone is quite sharp. The hole was drilled to a total depth of 187 ft (57 m) and bottomed out in shale (see appendix 4).

Holes 3–97 through 6–97, north of hole 2–97, were drilled to test the northern extent of the sill (fig. 6). In drill hole 3–97 lamproite was again found below a shallow soil cover and reached a minimum thickness of 84 ft (26 m), and as expected, was underlain by metamorphosed shale. The sill again appears to dip to the north. The lamproite sill extends north to drill hole 4–97 and is overlain by 9 ft (3 m) of metamorphosed shale. In drill hole 5–97, a 47-ft (14-m)-thick lamproite sill is present. The hole was completed to a depth of 104 ft (32 m). The top 20 ft (6 m) is black shale that becomes hard, metamorphosed, and contains many pyrite-filled fractures. The shale below the lamproite is likewise metamorphosed. In drill hole 6–97, on top of the low hill, no lamproite sill is encountered. The hole was completed to a depth of 137 ft (42 m) and the first 15–18 ft (4.6–5.5 m) consist of gray siltstone. Below that depth siltstone and shale become progressively more altered and again show many high-angle, pyrite-filled fractures. Lamproitic inclusions, 3–18 inches (7.5–45 cm) in size, occur in the last 5 ft (1.5 m) towards the bottom of the metamorphosed interval at 97 ft (30 m). Below this unaltered gray siltstone and shale make up the rest of the section (see appendix 4). Hole 7–97 was drilled due south of hole 2–97 with the purpose of tracing the sill found in hole 3–97 farther to the south (fig. 6). The hole was drilled to a depth of 188 ft (57 m). In this hole a 71-ft (22-m)-thick lamproite sill occurs at a depth of 42 ft (13 m), sandwiched between a sequence of limestones (see appendix 4). Apparently this is not the same sill as the one encountered in drill hole 3–97, unless there is a reversal in dip of the sill as possibly is the case between drill holes 2–92 and 5–95 (fig. 15).

To explore a possible eastward continuation of the sill encountered in drill hole 7–97, drill hole 8–97 was spotted close to 1/4 mi (0.4 km) to the southeast (fig. 6). Lamproite was found

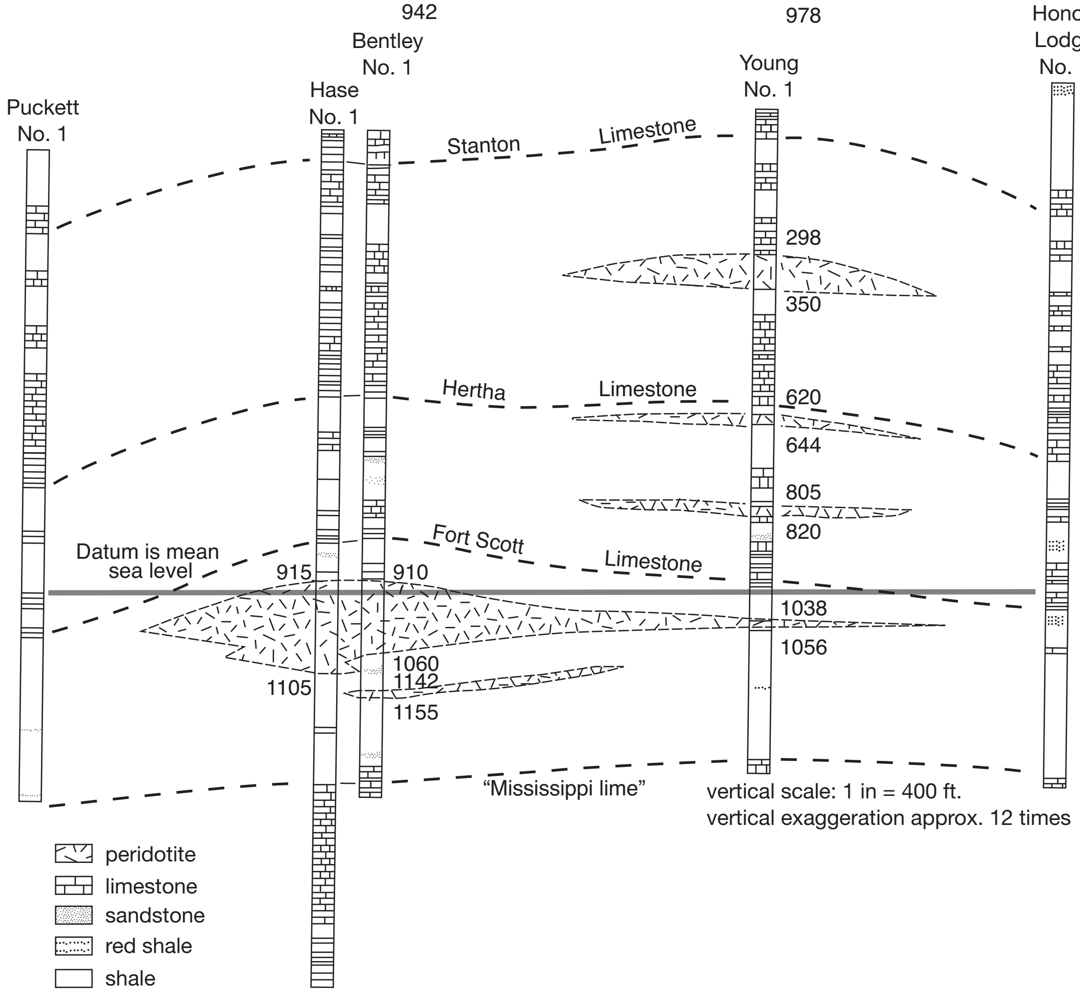


FIGURE 11—A west-east cross section through the southern half of Silver City Dome showing the location of lamproite sills in the subsurface as interpreted by Wagner (1967).

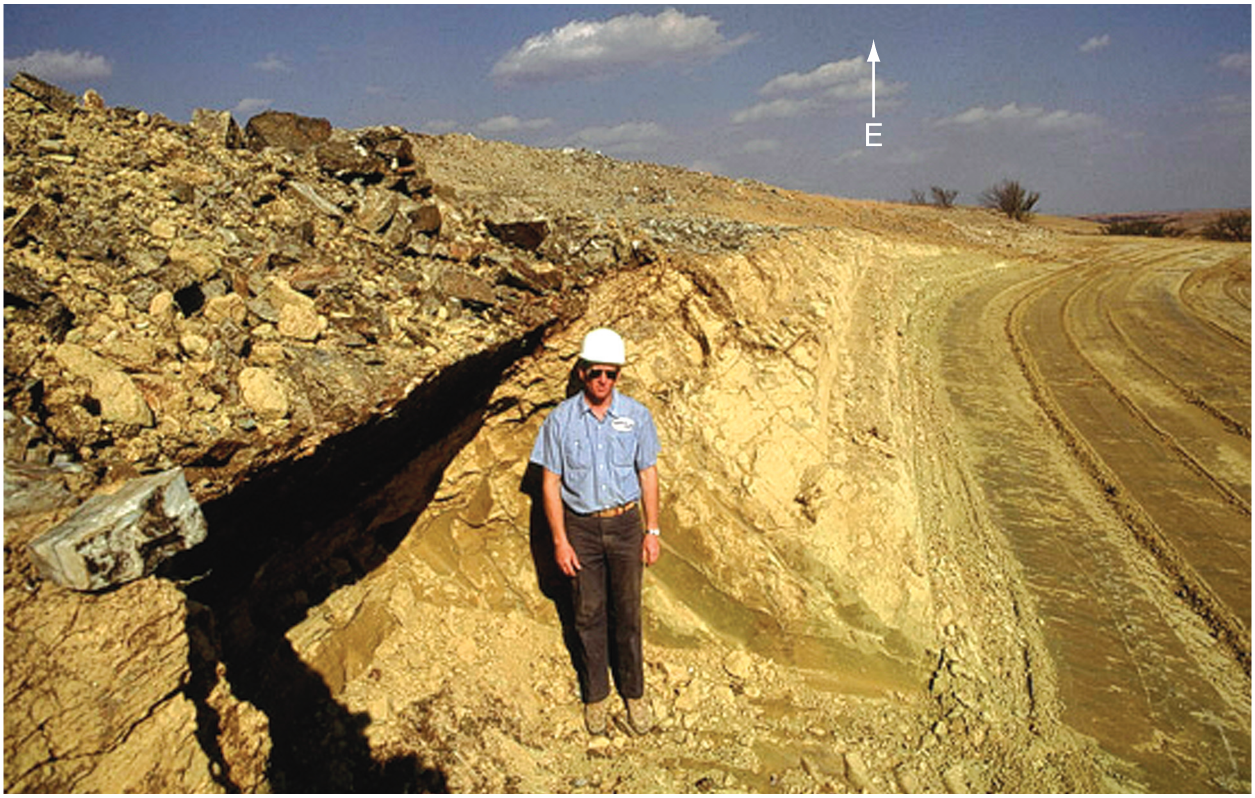


FIGURE 12—Steeply north-dipping fault separating the altered olive-colored lamproite to the south from the sandstones and shales of the Stranger Formation to the north.

FIGURE 13—Aerial view of the open-pit mine operated by Micro-Lite LLC.

under a shallow soil cover extending down to a depth of 66 ft (20 m) and underlain by limestone (see appendix 4). Hole 9–97 was spotted to the northeast of drill hole 8–97 to evaluate the northerly continuation and dip of the lamproite sill (fig. 6). In drill hole 9–97, located in the central western part of sec. 33, a 79-ft (24-m)-thick lamproite sill occurs at a depth of 28 ft (8.5 m), only about 5 ft (1.5 m) below the contact with overlying limestone and shale (see appendix 4). Possibly the same sill can also be found in drill hole 10–97, located northwest of drill hole 9–97 (fig. 6). Here a 68-ft (21-m)-thick lamproite sill is found in the same stratigraphic position as in drill hole 9–97 (fig. 16). It appears that the sill encountered in the last four drill holes dips to the north (see appendix 4).

Hole 11–97 was drilled still farther to the northwest (fig. 6) and intersected a 74-ft (23-m)-thick lamproite sill at a depth of 75 ft. The sill intruded at the contact between the overlying shale and the underlying limestone (see appendix 4). Drill hole 12–97 is halfway between drill holes 7–97 and 12–92 (fig. 6). At this location a 72-ft (22-m)-thick lamproite sill intruded in between limestone at a depth of 59 ft (18 m; see appendix 4).

During the 1998 drilling season, six holes were drilled at Silver City Dome. These holes were spread over sec. 32 to test some of the areas outside the area of more intense drilling and to pinpoint the location of known sills more accurately.

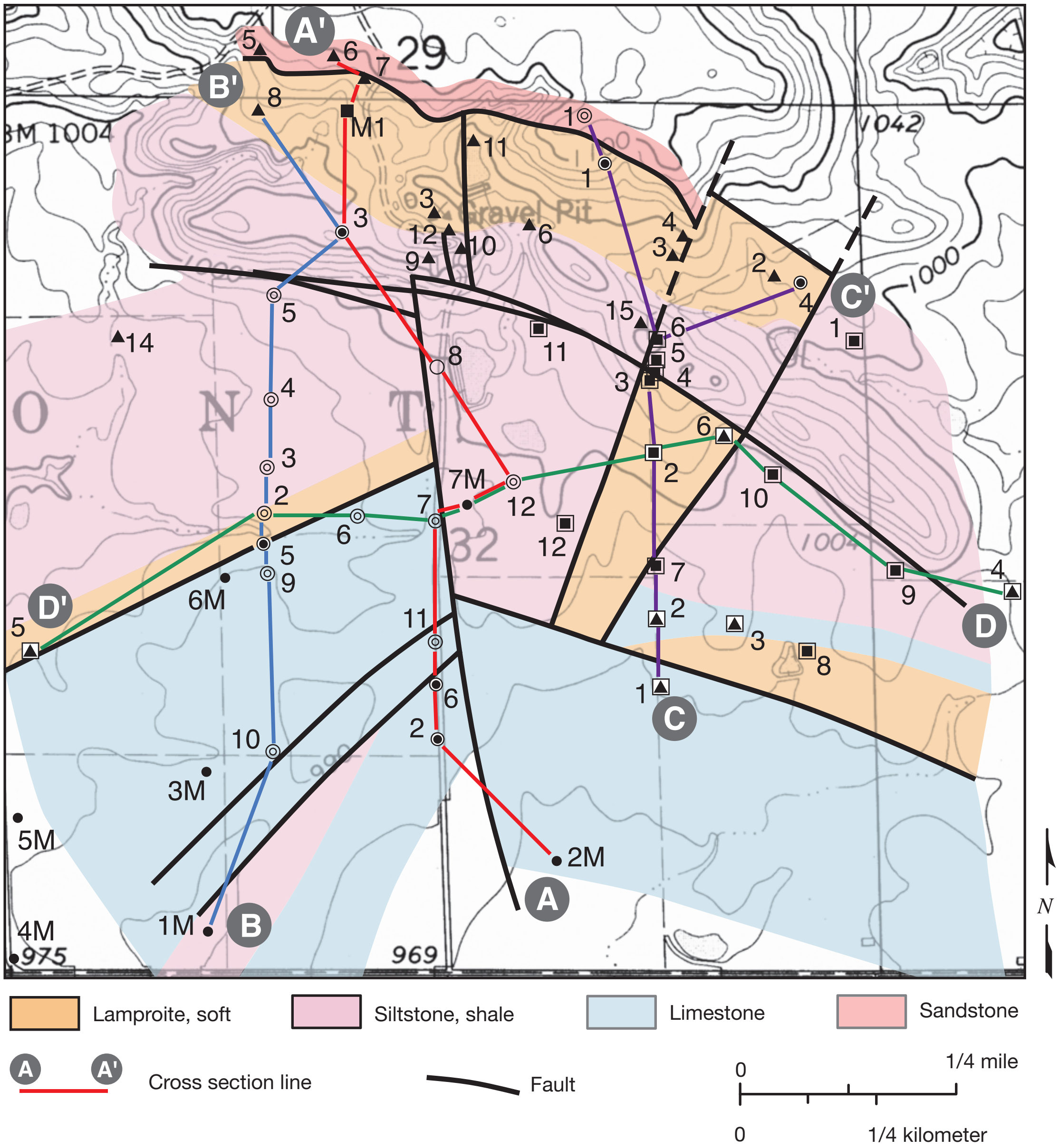
Drill holes 1–98, 2–98, and 3–98 were drilled relatively close to each other and south of drill holes 7–97 and 8–97 (fig. 6). Hole 1–98 was drilled due south of 7–97. The 79-ft (24-m)-thick lamproite sill present in hole 7–97 is missing in this hole (fig. 18). Instead 70 ft (21 m) of limestone is encountered, underlain by a 49-ft (15-m)-thick section consisting of a mixture of metamorphosed limestone, shale, and lamproitic material. The rock contains many fractures, some of which are open and filled with secondary calcite. Below this is 25 ft (7.6 m) of black shale, followed by 6 ft (1.8 m) of lamproite. Alternating unaltered limestone and shale units make up the rest of the section down to the total depth of 296 ft (90 m; see appendix 5). Hole 2–98 was spotted halfway between 1–98 and 7–97 (fig. 6). In this drill hole a 79-ft (24-m)-thick lamproite sill was found in the same stratigraphic position as in drill hole 7–97 (fig. 18). Drill hole 3–98, situated halfway between drill holes 7–97 and 8–97 (fig. 1), encountered a 76-ft (23-m)-thick lamproite sill at only 6 ft (1.8 m) below the surface (see appendix 5). This is probably the same sill as in drill holes 7–97 and 8–97.

In drill hole 4–98, located east of drill hole 9–97 (fig. 6) in the western part of sec. 33, only a thin, 7-ft (2-m)-thick lamproite is encountered at a depth of 90 ft (27 m; fig. 16). The hole was drilled to a total depth of 208 ft (63 m; see appendix 5).

Drill hole 5–98 was spotted in the south-central western part of sec. 32 (fig. 6). At this location 22 ft (6.7 m) of lamproite occurs at a depth of 8 ft (2.4 m) below a shallow soil cover and a couple of feet of limestone (fig. 16, see appendix 5). The final drill hole, 6–98, was spotted in between drill holes 3–97 and 10–97 (fig. 6) to evaluate the continuity of the lamproite sills encountered in the latter two holes (fig. 16). In drill hole 6–98, the top of a 73-ft (22-m)-thick lamproite is exposed at the surface and is underlain by shale (see appendix 5).

In 1952, H. Wagner (unpublished material) described samples (see appendix 6) from 21 shallow core holes drilled at Silver City Dome (fig. 19) in 1944 to assess the quartzite as a possible aggregate resource. Five drill holes (11, 14, 16, 18, 21) intersected igneous rock. Most of the holes were drilled north of the exposed sill, where quartzite, shale, siltstone, and sandstone make up the section.

Nine holes were drilled in sec. 32 in 1958 under the direction of Paul C. Franks (fig. 6, table 6; see appendix 7). The holes were drilled with a rock bit, but some core was taken from a second drill hole spotted close by (No.1A [Hill] and No. 2A [Hill]), to better define some of the lamproite sills. Drill hole No. 1M (Hill) was spotted in the southwestern part of sec. 32 (fig. 6) and completed to a depth of 795 ft (242 m; table 6; see appendix 7). At this location two or possibly more lamproite sills were encountered. The reason for the uncertainty is that poor sample recovery of the deeper sill or sills prevented definition of individual sills. A 23-ft (7-m)-thick sill occurred at a depth of



Drill Holes

1958	1989	1991		1992		1995	1997	1998
●	■	▲		◎		◉	▣	◬
1M (Hill)	M1	1=1-91	9=9-91	1=1-92	7=7-92	1=1-95	1=1-97	1=1-98
1A (Hill)		2=2-91	10=10-91	2=2-92	8=8-92	2=2-95	2=2-97	2=2-98
2M (Hill)		3=3-91	11=11-91	3=3-92	9=9-92	3=3-95	3=3-97	3=3-98
2A (Hill)		4=4-91	12=12-91	4=4-92	10=10-92	4=4-95	4=4-97	4=4-98
3M (Hill)		5=5-91	13=13-91	5=5-92	11=11-92	5=5-95	5=5-97	5=5-98
4M (Hill)		6=6-91	14=14-91	6=6-92	12=12-92	6=6-95	6=6-97	6=6-98
5M (Hill)		7=7-91	15=15-91				7=7-97	
6M (Hill)		8=8-91	16=16-91				8=8-97	
7M (Hill)							9=9-97	
							10=10-97	
							11=11-97	
							12=12-97	

FIGURE 14—Geology and distribution of lamproite sills based on drill-hole information. Also shown is the location of cross sections A-A´, B-B´, C-C´, and D-D´.

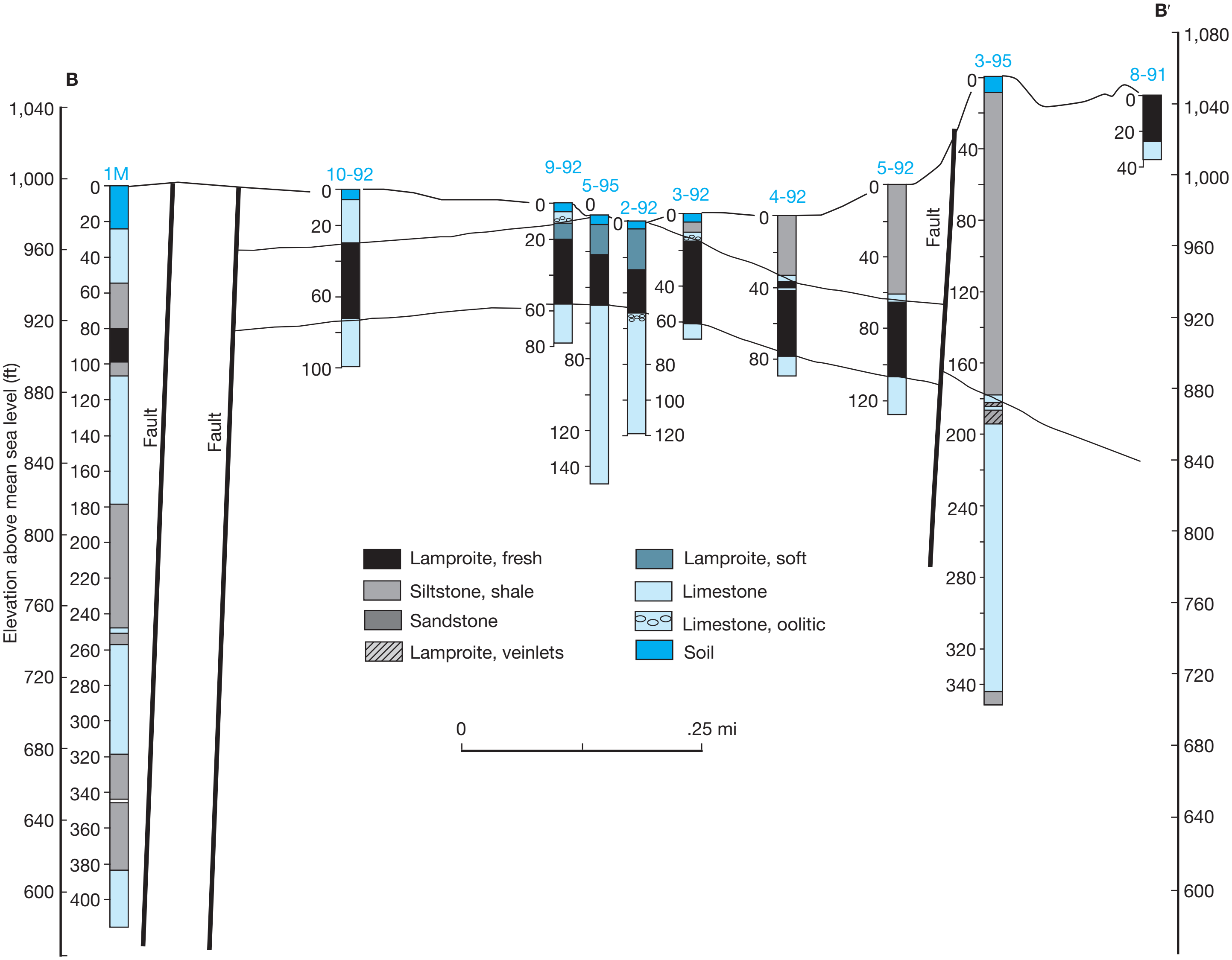


FIGURE 15—South-north cross section B-B´ showing the distribution and location of lamproite sills in the northeastern part of Silver City Dome.

80 ft (24 m). Below 731 ft (223 m) one or possibly three closely spaced lamproite sills occur. It also appears from the drillers log that there may be some mixed lamproite, metamorphosed shale present. The upper sill occurs in the Vilas Shale and the lower lamproite sill occurs in the Pleasanton Group (see appendix 7).

The No. 1A (Hill) hole was drilled at the same location as the No. 1M (Hill), presumably to better define the thickness and depth of the upper lamproite sill. In this drill hole the 27-ft (8-m)-thick sill occurs at a depth of 81 ft (24.7 m; table 6).

The No. 2M (Hill) drill hole was spotted in the center SW SE of the section and was completed to a depth of 524 ft (160 m; table 6, fig. 6; see appendix 7)). Three lamproite sills were encountered. The uppermost sill is 7 ft (2 m) thick and occurs at a depth of 61 ft (19 m) at the contact between the Vilas Shale and the overlying Stanton Limestone. A 20-ft (60-m)-thick sill occurs at a depth of 300 ft (92 m) in the Iola Limestone. The third sill has a minimum thickness of 15 ft (4.6 m) and occurs at the bottom of the hole in what is tentatively identified as the Cherryvale Shale.

Drill hole No. 2A (Hill) was spotted 30 ft (9 m) southwest of drill hole No. 2M (Hill) (fig. 6) to verify the thickness of the upper sill. The sill was found to occur at a depth of 61.5 ft (18.8 m) and is 7.5 ft (2.3 m) thick. Total depth of the drill hole is 70.5 ft (21.5 m; table 6).

Drill hole No. 3M (Hill) was spotted near the northeast corner of the SW SW sec. 32 (fig. 6). A lamproite sill having a minimum thickness of 33 ft (10 m) was encountered at 73.5 ft (22 m) and extended down to the total depth of 106.8 ft (32.6 m). This drill hole is just to the west of drill hole 10–92 (table 6; see appendix 7).

Drill hole No. 4M (Hill) was spotted in the extreme southwest corner of sec. 32 (fig. 6) and completed to a depth of 100 ft (30.5 m; table 6; see appendix 7). A 12-ft (3.7-m)-thick lamproite sill occurs at a depth of 30.7 ft (9.4 m). Drill hole No. 5M was also spotted in the southwestern part of sec. 32, 1,275 ft (389 m) north of drill hole No. 4M (fig. 6). No record of the top 26 ft (8 m) is reported, but below that 7.8 ft (2.4 m) of lamproite was encountered (table 6; see appendix 7). Drill hole 5–98 to the north of it contains lamproite at a shallow depth below some limestone. This may be the same sill as in drill hole 5M. Drill hole No. 6M (Hill) located just west of drill holes 2–92 and 5–95 (fig. 6) bottomed out at 52 ft (16 m). A lamproite sill having a minimum thickness of 28.5 ft (8.7 m; table 6; see appendix 7) was intersected at a depth of 23 ft (7 m). The lower contact with underlying shale is at 51.5 ft (15.7 m), but the upper contact could not be established because no samples were recovered. Drill hole No. 7M (Hill) is located near the center of sec. 32 (fig. 6) and also reached a depth of 52.5 ft (16 m). No samples

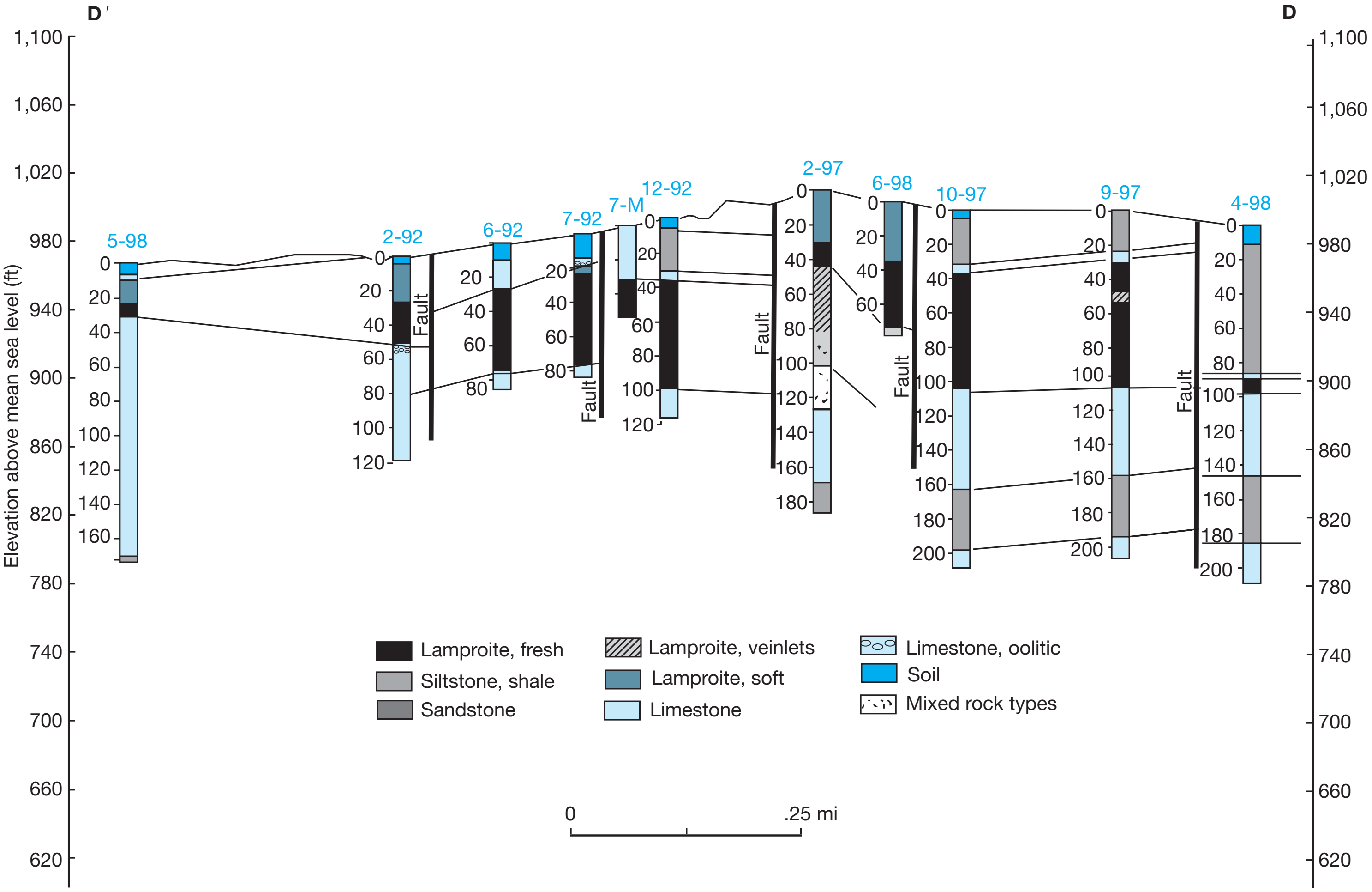


FIGURE 16—East-west cross section D-D´ showing the distribution and location of lamproite sills in the northeastern part of Silver City Dome.

were recovered for the first 31.5 ft (9.6 m). Below this depth a lamproite sill having a minimum thickness of 21 ft (6.4 m) was intersected (table 6; see appendix 7). Thus no top or bottom contact of the sill with enclosing sediments was established.

Examining the data on the occurrence of lamproite sills at Silver City Dome, the following conclusions can be drawn:

- Lamproite sills can vary in thickness from less than a foot to over 100 ft (30.5 m).
- Thickness of individual sills seems to have no relationship to the depth at which they are found, even though the thickest sills encountered so far occur at shallow depths.
- Individual sills can only be correlated over short distances.
- No good evidence exists that sills thin appreciably between relatively close-spaced drill holes.
- All sills appear to be dipping. Where enough drill-hole information is available in the northern part of the dome, the sills can be ascertained to dip either in a northerly or a southerly direction.

Rose Dome: More than 50 oil-exploration holes have been drilled at Rose Dome and the sections immediately surrounding it. The total number of drill holes is difficult to determine, because a large number of the holes were drilled many years ago and the records are either missing or incomplete. Drill-hole locations for which detailed records are available are shown in fig. 9 and listed in appendix 9. The explorationists were only interested in the oil and gas potential of the Pennsylvanian sandstones, and consequently practically all drill holes bottom out in the Lower Pennsylvanian at depths of 1,100 to 1,500 ft (336–468 m).

In 1964 the Kansas Geological Survey drilled five holes on Rose Dome (fig. 9, table 7). The holes were drilled just west of US–75 on the topographic high where rounded granite boulders, up to several feet in diameter, are exposed at the surface. Almost all the core and samples recovered have been lost and those that are available have been compromised. The deepest hole reached 90 ft (27 m) and encountered seven lamproite sills, the thickest being almost 12 ft (3.7 m; see appendix 7).

In 2001, a hole was drilled in the eastern part of the dome to test Pennsylvanian coal beds for their methane content. The geologist logging the hole (Michael Ebers, personal communication, 2001) noticed igneous rock at a depth of about 400 ft (122 m) and notified the author of this occurrence. Following up on this information the Kansas Geological Survey drilled and cored two holes on the topographic high east of US–75 in the northeastern part of Rose Dome (fig. 9) in 2002. Core hole Eagle 4 (fig. 20) was drilled to a depth of 850 ft (259 m) and encountered five lamproite sills, the thickest being 41.4 ft (12.6 m; fig. 19; see appendix 10). Core hole Eagle 5 was completed to a depth of 992 ft (303 m; fig. 20) and encountered four lamproite sills, the thickest being 67 ft (20 m; see appendix 10). The lamproite at Rose Dome has the same appearance as the lamproite at Silver City Dome, but petrographically the rock is different. The differences will be described in the section on petrography.

The two drill holes are about 1,700 ft (519 m) apart. It is tempting to correlate the lamproite sills in the two drill holes, but only the thin upper and lower lamproite sills occur at roughly the same depth, while a correlation between the thick lamproite sills is more problematic.

TABLE 5—Hole drilled in 1988 by the Kansas Geological Survey at Silver City Dome.

Drill Hole	Spot Location	Depth (ft, inches)	Thickness (ft)	T.D. (ft)
Ecco Ranch #1	SW NW NE sec. 5,	49–70.5	21.5	812
	T. 27 S., R. 15 E.	255–256	1?	
		313.5–317.5	4	
		408–408.5	P	
		577?–583?	6	
		691–692	1	
		734.5–743	8.5	
		771–778.5	7.5	

TABLE 6—Holes drilled in 1958 by the Kansas Geological Survey at Silver City Dome.

Drill Hole	Spot Location	Depth (ft, inches)	Thickness (ft)	T.D. (ft)
No. 1M (Hill)	sec. 32, T. 26 S., R. 15 E.	80–103	23	795
	1200 ft E, 200 ft N, SW cor.	731–795	64?	
No. 1A (Hill)	sec. 32, T. 26 S., R. 15 E.	81.2–108.3	27.1	110.8
No. 2M (Hill)	sec. 32, T. 26 S., R. 15 E.	61–68	7	524.5
	center SW SE	300–320	20	
		509–T.D.	>15	
No. 2A (Hill)	sec. 32, T. 26 S., R. 15 E.	61.5–69	7.5	70.5
	30 ft SW of N, 2M			
No. 3M (Hill)	sec. 32, T. 26 S., R. 15 E.	73.5–T.D.	>33.3	106.8
	50 ft N, 50 ft W, NE cor.			
No. 4M (Hill)	sec. 32, T. 26 S., R. 15 E.	30.7–42.7	12	100
	100 ft E, 100 ft N, SW cor.			
No. 5M (Hill)	sec 32, T. 26 S., R. 15 E.	?–33.8	>7.8	37.5
	100 ft E, 1,275 ft N, SW cor.			
No. 6M (Hill)	sec. 32, T. 26 S., R. 15 E.	?–51.5	>28.5	52
	1330 ft E, 2,745 ft N, SW cor.			
No. 7M (Hill)	sec. 32, T. 26 S., R. 15 E.	?–T.D	>21	52.5
	2650 ft E, 2,745 ft N, SW cor.			

Structure of the Domes

Silver City Dome

Structurally both domes are very similar. However, much more information is available for Silver City Dome, and therefore, its structure will be discussed first.

Wagner (1954) mapped and recognized the steeply north-dipping fault along the northern flank of Silver City Dome, together with a minor subsidiary fault about 800 ft (244 m) to the south (fig. 5). Wagner (1954) suggested that equivalent rock units on the south side of the fault are lower than those on the north side and show a relative displacement on the order of 20–200 ft (6–61 m). Just north of the fault, in the southwestern part of sec. 29, T. 26 S., R. 15 E. (fig. 2), the Tonganoxie Sandstone Member is well exposed. In drill holes M1, 8–91, 1–95, and 3–95, all a short distance south of the fault, up to 190 ft (58 m) of the Weston Shale Member is encountered. Therefore, if there is a large displacement on the fault one would expect to encounter the Tonganoxie Sandstone Member in the drill holes south of the fault. Thus, it is concluded that the displacement on the fault is minimal.

With minor exceptions the fault marks the boundary between igneous rock to the south and sedimentary rock to the north (figs. 5, 14). Our studies show that south of the fault some isolated, detached blocks of metamorphosed sedimentary rocks have been caught up and possibly transported by the lamproite magma. Poor exposures prevented Wagner (1954) from determining the exact position of the fault. Wagner (1954) traced the fault in an east-southeasterly direction into sec. 33, T. 26 S., R. 15 E., to a prominent hill on which the Haskell Limestone Member of the Lawrence Formation is exposed (fig. 10). Our drilling confirms

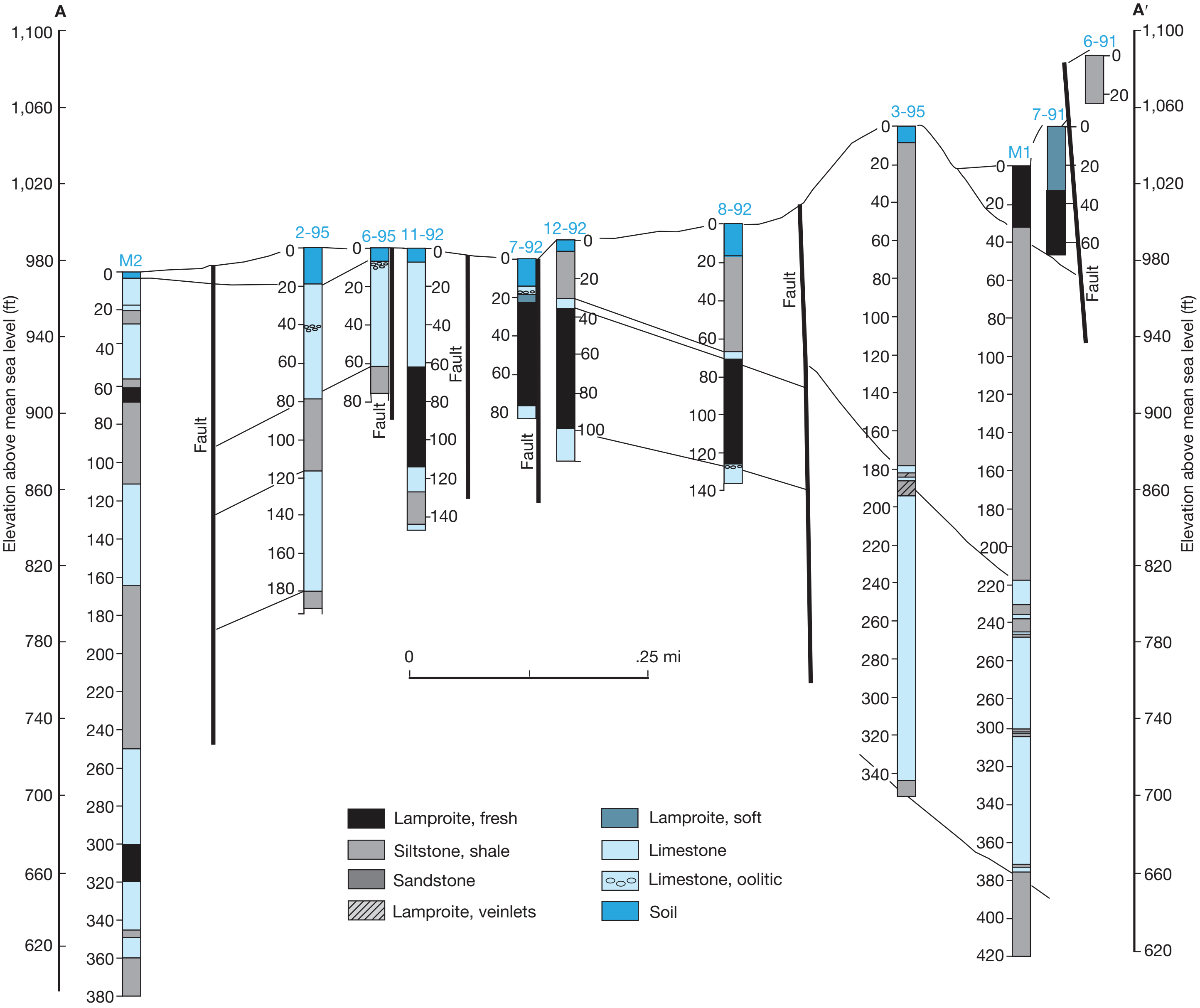


FIGURE 17—South-north cross section A-A´ showing the distribution and location of lamproite sills in the northeastern part of Silver City Dome

the location of the fault in the north-central part of sec. 32. However, in the eastern quarter of the section, the fault takes on a more southeasterly trend and shows a minor offset along a crosscutting northeast-trending fault (fig. 10).

In 1991, we drilled a hole east of the then-existing open pit close to the fault. In this drill hole, 3–91 (fig. 6; see appendix 1), the top 14.4 ft (4.4 m) consisted of altered shale and sandstone (slate and quartzite) followed by 113 ft (34 m) of lamproite and underlain by more shale. The sill dips 2°–3° to the north and attains its greatest thickness as it approaches the fault. To the south erosion causes the sill to thin to a featheredge against the set of low hills. To the east the sill is interpreted to terminate against a northeast-trending fault. Farther to the east the lamproite sill extends to just beyond drill hole 4–95 (fig. 6; see appendix 3). In this drill hole 26 ft (8 m) of lamproite occur beneath a shallow soil cover. In hole 1–97 (fig. 6; see appendix 4), drilled to a total depth of 178 ft (54 m), no lamproite is encountered. To the west the sill pinches out (fig. 21) against the fault, and this is clearly shown by the exposures in the present-day mining operations.

In the west half of sec. 32, Wagner (1954) shows two small lamproite outcrops (fig. 5). The most westerly occurrence, located in a creek bed, was confirmed, but the other outcrop could not be located. Drill hole 2–92 (fig. 6) was spotted at the location where the lamproite occurs near the surface under about 5 ft (1.5 m) of soil (fig. 15). The lamproite sill at this location is 46 ft (14 m) thick. This sill was traced in a northerly direction by drilling holes 3–92, 4–92, and 5–92 (figs. 6, 15). The sill dips to the north at the same angle (2°–3°) as the sill north of the set of low hills, and the thickness of the sill remains constant. Drill hole 3–95 was drilled on top of the hill north of drill hole 5–92 (fig. 6) to a depth of 350 ft (107 m). No lamproite was encountered in this drill hole (see appendix 2), but at a depth of about 182 to 198 ft (56–60 m), where one might expect to intersect the dipping sill to the south, the nearby presence of lamproite is evident. The rock in this interval changes from predominantly shale of the Stranger Formation above to limestone of the South Bend Limestone Member below. At 182.2 ft (55.6 m) igneous rock intrudes along a high-angle fracture into the limestone. Below, this greenish-

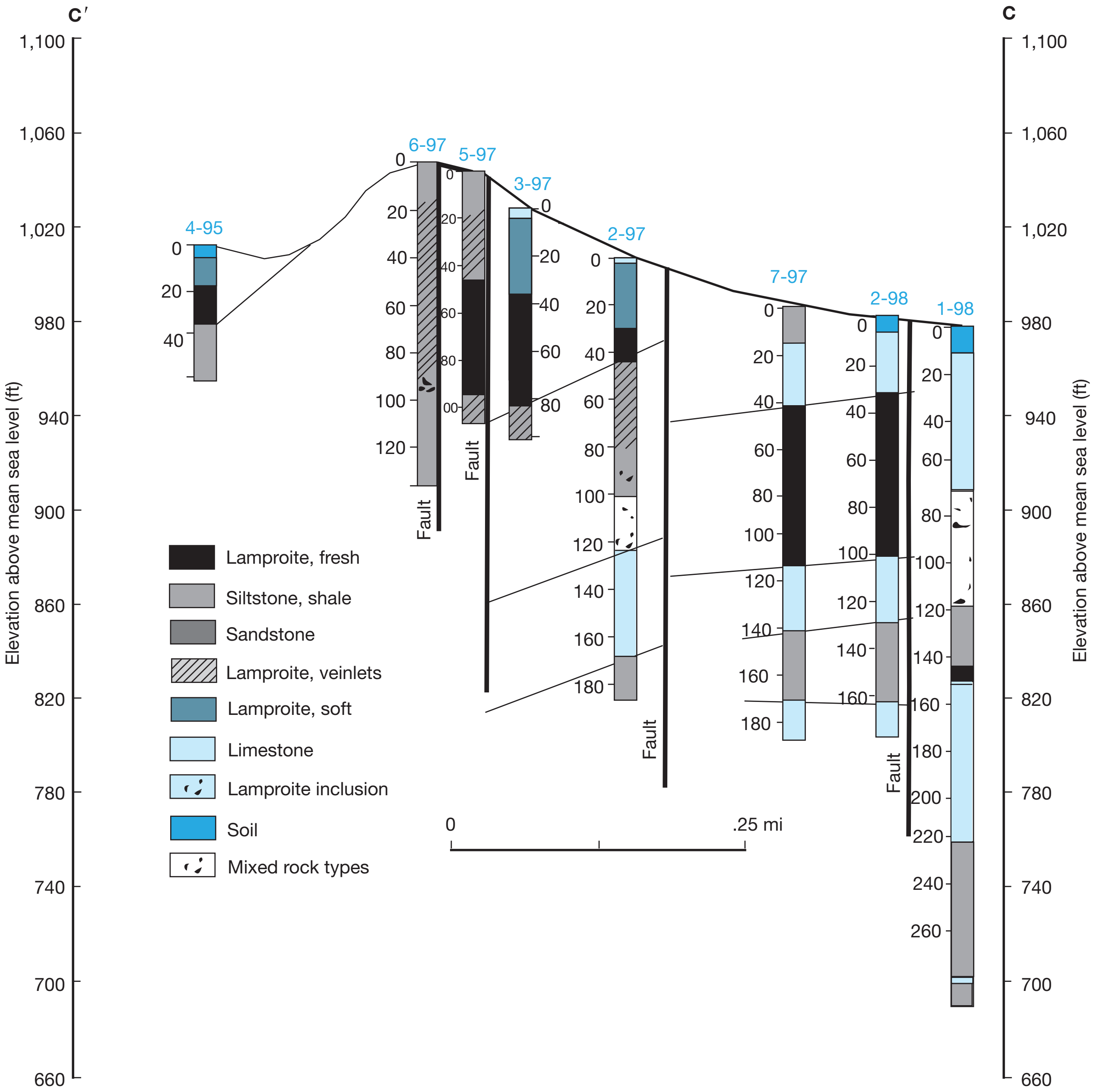


FIGURE 18—South-north cross section C-C´ showing the distribution and location of lamproite sills in the northeastern part of Silver City Dome.

brown igneous rock, some of it containing shale and limestone clasts, or otherwise contaminated with sedimentary material, occurs. Because of the amount of contamination, the igneous rock is not good lamproite and contains very little phlogopite. The shale of the Stranger Formation contains many high-angle fractures, some of which are healed and filled with secondary minerals such as calcite. We interpret the drill hole to be very close to a fault separating and terminating the lamproite sill to the south from rocks to the north. Residual fluids associated with the lamproite magma moved laterally for a short distance and affected the rocks in drill hole 3–95 (fig. 15).

The sill encountered in drill holes 5–95, 9–92, and 10–92 (fig. 6) dips at a low angle (<2°) in a southerly direction, opposite to the dip of the same sill farther to the north. The same sill extends in a westerly direction towards drill hole 3M, about 300 ft (91.5 m) west of drill hole10–92 (fig. 6). In this drill hole a lamproite sill having a minimum thickness of 33.3 ft (10 m) was encountered at a depth of 73.5 ft (22 m; see appendix 2). No samples were recovered above this depth.

Hole 5–95 was drilled to try to get better information about what might be the cause for the change in dip of the sill (fig. 15). The drill hole did not resolve the problem. It is believed that the northerly and southerly dipping sills are the same sill, and a fault in the vicinity of drill hole 5–95 caused the change in dip. In the sample description of drill hole 5–95 (see appendix 3), it was noted that the rock is very fractured in the interval between 37 and 57 ft (11 and 17 m).

Farther to the west, in drill hole 14–91, a 7-ft (2 m) lamproite sill occurs at a depth of 72 ft (22 m; fig. 6; see appendix 1). This sill is interpreted to be a separate sill and not connected to the 46-ft (14-m)-thick sill to the east.

Drill holes 6–92 and 7–92 were completed east of drill hole 2–92 (fig. 6). The thickness of the lamproite sill in the two holes is 50 ft and 57 ft (15 and 17 m), respectively. The thickness is

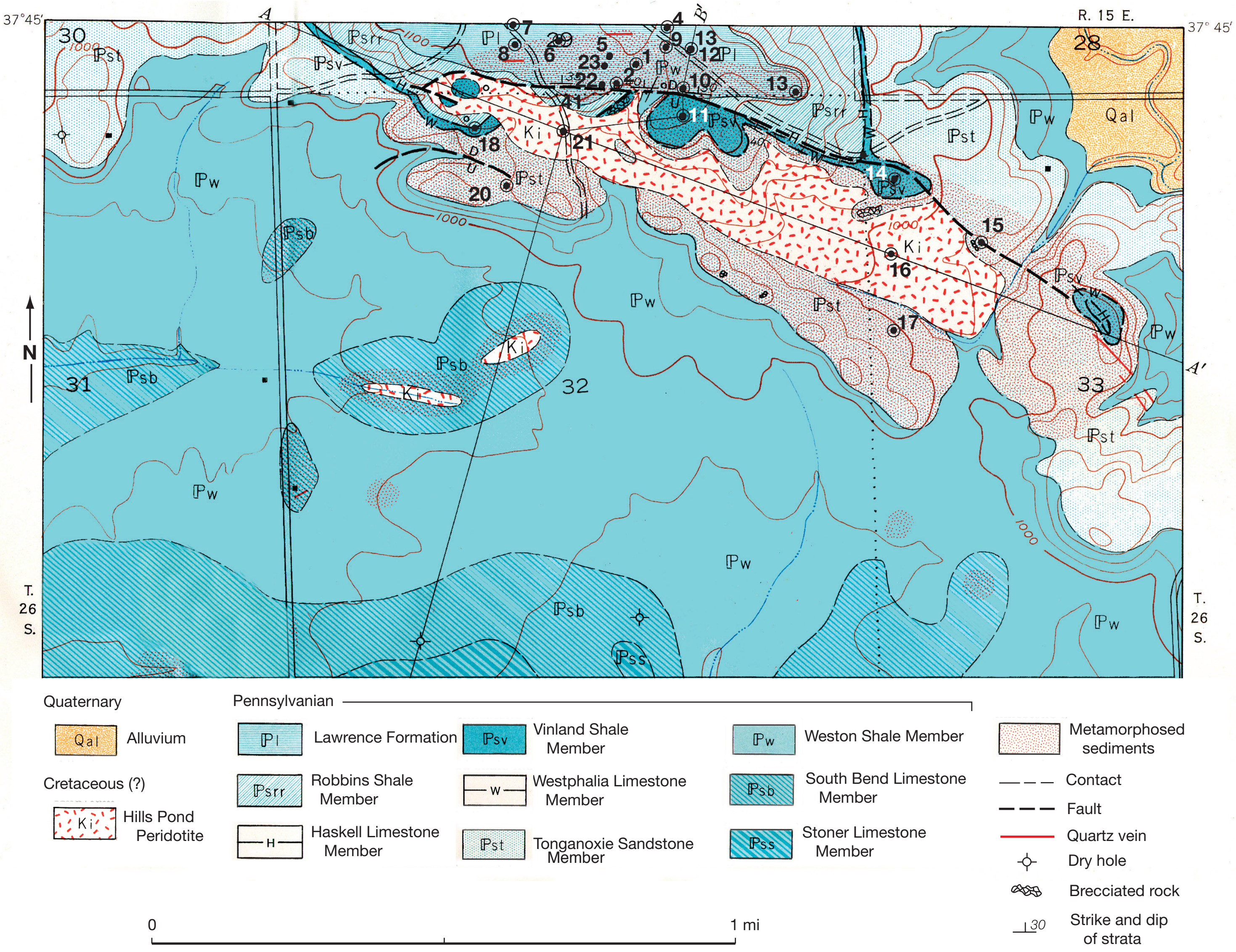


FIGURE 19—Location of holes drilled in 1952 by H. Wagner in the northeastern part of Silver City Dome.

TABLE 7—Holes drilled by the Kansas Geological Survey in 1964 at Rose Dome.

Drill Hole	Spot Location	Depth (ft)	Thickness (ft)	T.D. (ft)
DDH-1	sec. 13, T. 26 S., R. 15 E. 1,876 ft N, 1,157 ft W, SE cor.	?	?	22
DDH-2	sec. 13, T. 26 S., R. 15 E. 1,868 ft N, 1,202 ft W, SE cor.	25?–26? 28?–29?	1 1	55.9
DDH-3	sec. 13, T. 26 S., R. 15 E. 1,866 ft N, 1,240 ft W, SE cor.	26?–28.7 29.7–32 67.7–70?	~2.7 2.3 ~2.3	90.1
DDH-4	sec. 13, T. 26 S., R. 15 E. 1,837 ft N, 1,125 ft W, SE cor.	24.8?–38? 42.2?–46.5	~13.2 ~4.3	49.3
DDH-5	sec. 13, T. 26 S., R. 15 E. 1,720 ft N, 827 ft W, SE cor.	9.8–17.6	7.8?	24
Eagle 4	sec. 18, T. 26 S., R. 16 E. center NW SE	43.3–48.7 409.3–451.8	5.4 42.4	850.1
Eagle 5	sec. 18, T. 26 S., R. 16 E. center SE NE	50.2–54.7 361–428.1	4.5? 67.1	992.3

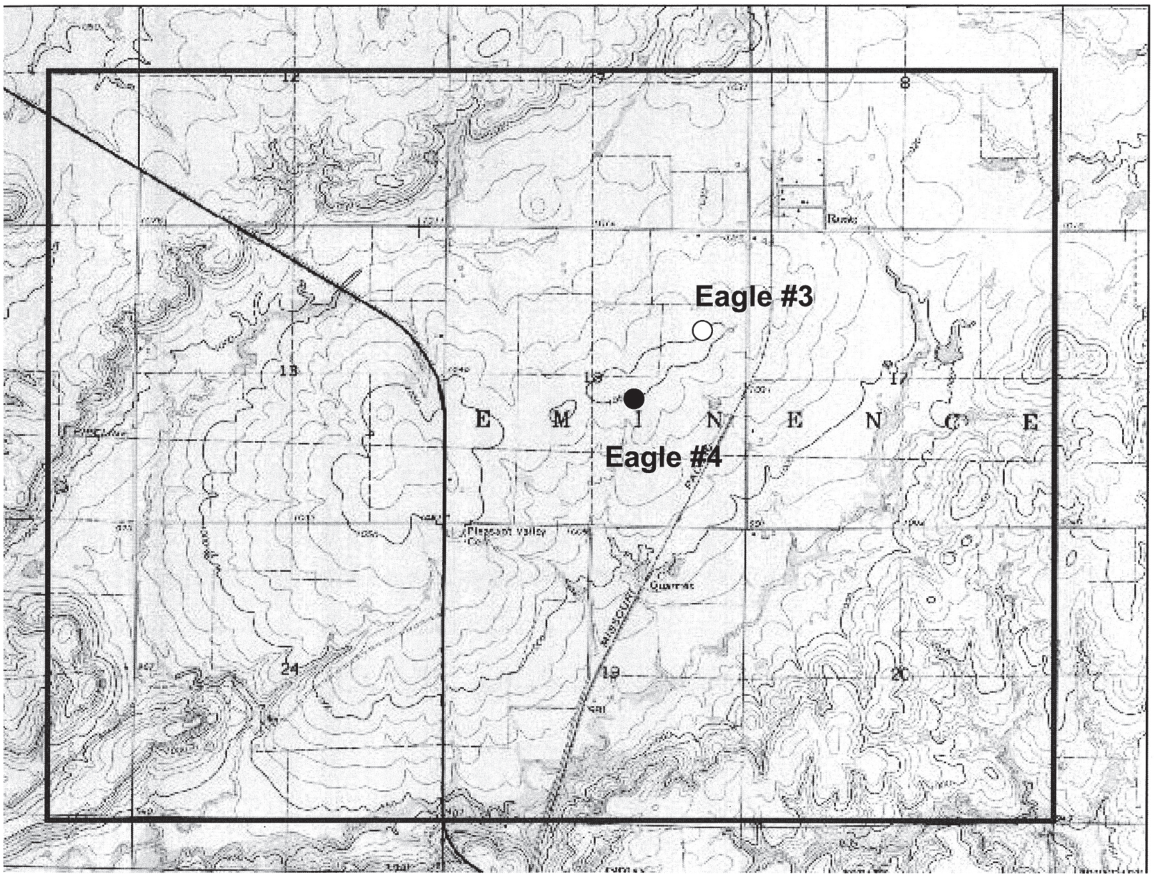


FIGURE 20—Location of the Eagle 4 and 5 drill holes on Rose Dome.

slightly more than in drill hole 2–92 and it is not certain whether it is the same or a different sill. Based on the thickness of the sill as well as the depth of occurrence below the surface, it appears that a fault may separate the sill in drill hole 2–92 from the sill in drill holes 6–92 and 7–92 (fig. 16).

To determine the continuity of the sills several holes were drilled south of drill hole 7–92 (fig. 6). They are drill holes 11–92, 2–95, and 6–95 (fig. 6). In drill hole 11–92 a 54-ft (16-m)-thick lamproite sill occurs at a depth of 61.6 ft (18.8 m). This may be the same sill as in drill hole 7–92 (fig. 17). If so, the sill dips south as does the sill encountered in drill holes 9–92 and 10–92. In drill holes 2–95 and 6–95, no lamproite was found and a fault probably terminates the lamproite sill found in drill hole 11–92 (fig. 17). In drill hole 2M, completed in 1958 (table 6; see appendix 7), three lamproite sills were encountered: one 7-ft (2-m)-thick sill at 61 ft (19 m), one 20-ft (6-m)-thick sill at 300 ft (92 m), and another sill having a minimum thickness of 20.5 ft (6 m) at the bottom of the hole. Therefore, another fault may occur between drill holes 2–95 and 2M (fig. 17).

Let us now analyze the information we obtained from drilling in the eastern part of sec. 32. Drill hole 2–97 is located alongside the north-south fence line halfway in the eastern part of sec. 32 (fig. 6). To our surprise a 44-ft (13-m)-thick lamproite sill is present under a couple of feet of soil cover (fig. 18; see appendix 4). The shale below the lamproite is metamorphosed for about 35 to 40 ft (11–12 m), decreasing towards the bottom. The shale is indurated and hard, and contains many fractures coated with pyrite. The shale extends down to about 102 ft (31 m), and in this interval inclusions of lamproitic rock are common. Inclusions range from small pieces up to ones several feet in size. Below this, in the interval between 102 ft and 123 ft (31–38 m), the rock consists of a mixture of lamproitic rock and limestone with minor shale in the upper part. The lamproitic material does not contain any phlogopite. Below this and down to the total depth of the drill hole at 187 ft (57 m), unaltered limestone and shale are present (see appendix 4). To establish the continuity of the sill, holes 3–97, 4–97, 5–97, and 6–97 were drilled to the north along the fence line (fig. 6). In drill hole 3–97 an 84-ft (26-m)-thick sill occurs under a couple of feet of soil cover. It is assumed that this is the same sill as in drill hole 2–97 (fig. 18; see appendix 4) and that about half of the lamproite in drill hole 2–97 was removed by erosion. The sill here dips at an angle of 5.4° to the north, which is about twice as much as the other sills that dip to the north. Drill hole 4–97 was spotted about 100 ft (30.5 m) north of drill hole 3–97 and about 10 ft (3 m) higher in elevation (fig. 6). In this 27-ft (8-m)-deep drill hole, lamproite occurs at a depth of 9 ft (2.7 m) and is overlain by metamorphosed shale (see appendix 4). The lamproite is probably the same sill as in drill hole 3–97 (fig. 18). Drill hole 5–97 is about the same distance north of drill hole 4–97 (fig. 6). In this drill hole the first 20 ft (6 m) consists of dark-gray shale. Below this the shale becomes increasingly more metamorphosed and fractured and shows a sharp contact with lamproite at 49.4 ft (15 m; see appendix 4). The underlying lamproite sill is 46 ft (14 m) thick and again is underlain by metamorphosed black shale. It is unclear what the relationship of this sill is with respect to the sill just to the south, but a fault must be present between drill holes 4–97 and 5–97 (figs. 6, 18). Drill hole 6–97 is located about the same distance north of drill hole 5–97 (fig. 6). In drill hole 6–97 no lamproite sill is encountered (see appendix 4). The top 12 ft (3.7 m) in this drill hole consists of siltstone that becomes slightly altered and fractured below this depth. Pyrite is common on the fracture

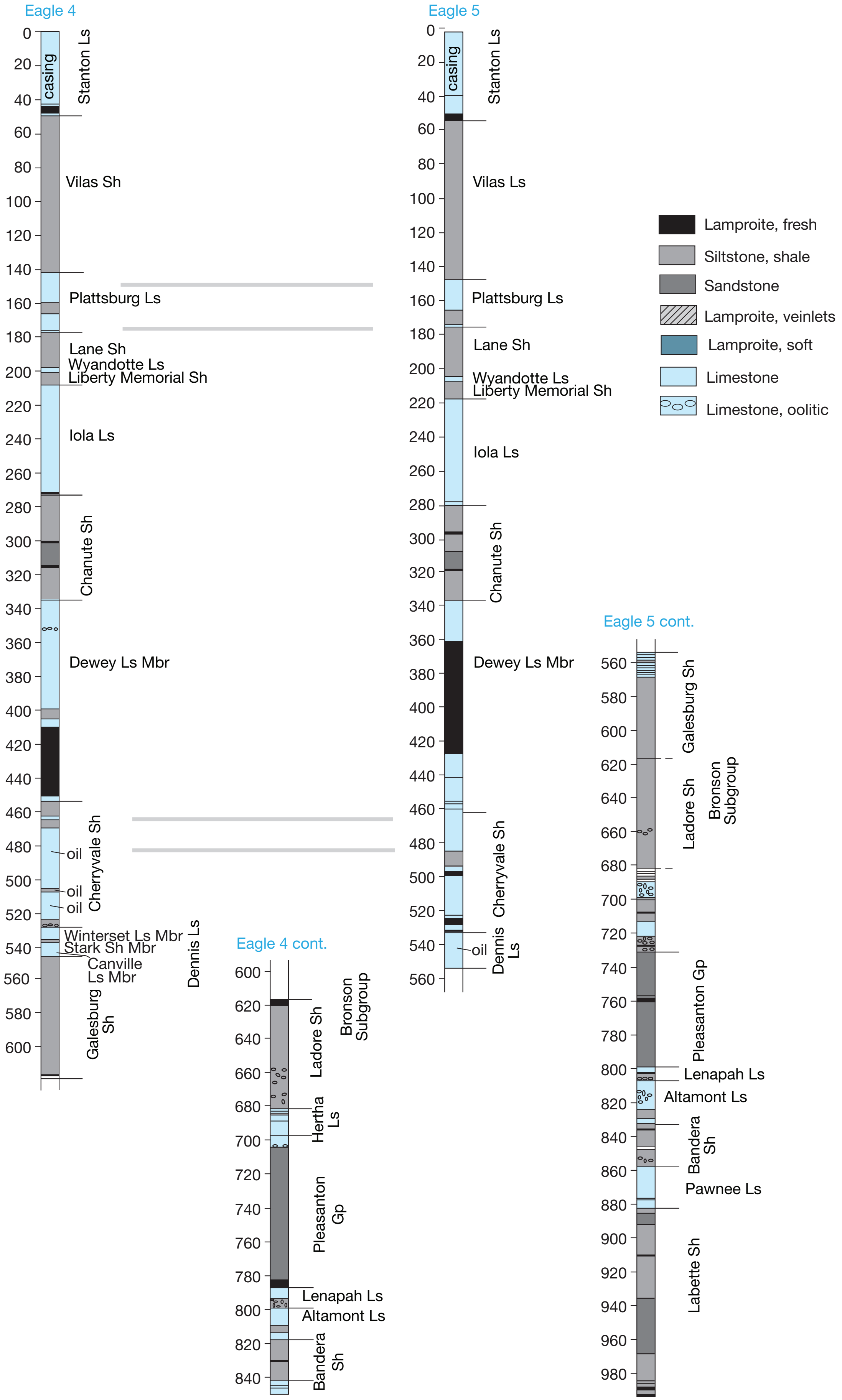


FIGURE 21—Stratigraphic log of the Eagle 4 and Eagle 5 drill holes on Rose Dome.

surfaces. In the interval between 87 ft and 92 ft (26.5–28 m), lamproite inclusions are common. Below this interval unaltered soft-gray to black shale occurs to the total depth of 137 ft (42 m). It is believed that the lamproite sill occurring in the holes to the south is cut off by a fault (figs. 14, 18). The sill in the above two drill holes probably extends to the east and can again be found in drill hole 6–98 (figs. 6, 14, 16; see appendix 5). The minimum thickness of the sill at this location is 72.4 ft (22 m), which is slightly less than the 84-ft (26-m)-thick sill found in drill hole 3–97. This is to be expected because of the location of the drill hole and the assumed dip of the sill. Farther south of drill hole 2–97, we drilled hole 7–97 (fig. 6). In this drill hole we encountered a 71-ft (22-m)-thick lamproite sill at a depth of 42 ft (13 m; see appendix 4). Except for the limestone in direct contact with the lamproite, none of the sedimentary rocks in this 188-ft (57-m)-deep hole showed any sign of having been altered. Because of the position of the lamproite sill as well as its thickness, it is believed that a fault separates the sill in drill hole 2–97 from the one found in drill hole 7–97 (fig. 18). Drill holes 1–98 and 2–98 are located south of drill hole 7–97 (fig. 6). In drill hole 2–98, a 70-ft (21-m)-thick sill occurs at a depth of 32 ft (9.8 m; see appendix 5). This sill is the same sill as the one in drill hole 7–97 (fig. 17). The apparent dip of the sill is on the order of 1.7° to the north, which is less than the sill to the north of it. In drill hole 1–98, a 48-ft (14.6-m)-thick section of metamorphosed shale and limestone mixed with lamproitic rock occurs (see appendix 5). A little farther down in the hole a 6-ft (1.8-m)-thick lamproite sill is present. A fault probably separates the rocks in this drill hole from those present in drill hole 2–98 north of it (figs. 14, 18). The fault is probably fairly close to drill hole 1–98, and the altered section and thin sill represent leakage of some lamproite across the fault plane.

To the west of drill hole 7–97, we spotted a number of holes to get information on the extent and possible connection between lamproite sills in the western half of sec. 32 and the sills to the east. In drill hole 12–97 (fig. 6), a 72-ft (22-m)-thick lamproite sill occurs at a depth of 59 ft (18 m; see appendix 4). In drill hole 12–92, a short distance to the northwest (fig. 6), a 64-ft (19.5-m)-thick lamproite sill is found at a depth of 36 ft (11 m; fig. 16; see appendix 2). About half-way between drill holes 7–92 and 12–92, the Kansas Geological Survey drilled hole 7M in 1958 (fig. 6; table 6) to a depth of 52.5 ft (16 m; see appendix 7). No samples were recovered from the upper 31.5 ft (9.6 m) of the hole, but below this a lamproite sill (peridotite) having a minimum thickness of 21 ft (6.4 m) was encountered. This is probably the same sill as the one occurring in drill holes 7–92 and 12–92 (fig. 16). In drill hole 8–92 (fig. 6), still farther to the northwest, a 56-ft (17-m)-thick lamproite occurs at a depth of 70 ft (21 m; fig. 17; see appendix 2). In drill hole 11–97 (fig. 6), east of drill hole 8–92, a 74-ft (22.6-m)-thick lamproite sill is present at a depth of 75 ft (23 m; see appendix 4). A southeast-northwest-trending fault just to the north of drill hole 11–97 terminates the lamproite sill (fig. 14). This fault is the same fault that terminates the lamproite sill present in drill hole 5–92 and also the one present in drill holes 3–97 and 6–98. Based mainly on geomorphic considerations, it is believed that the fault shows a minor offset north of drill hole 8–92 (fig. 14).

Four more holes were drilled in the eastern part of sec. 32. They are drill holes 8–97, 9–97, 10–97, and 3–98 (fig. 6). In each of these drill holes, as well as in drill holes 7–97 and 2–98, the same northward-dipping 70–78-ft (21–24-m)-thick lamproite sill was encountered (see appendices 4, 5). The dip of the lamproite sill is close to 1.5°.

More shallow drilling and augering information is available and included in appendix 6. From the information discussed in some detail here, the following conclusions can be drawn:

- At least three lamproite sills having distinctly different thicknesses can be identified in the shallow subsurface in sec. 32.
- With the exception of one sill, all other lamproite sills dip in a northerly direction.
- The dip of the sills varies from 1.5° to 5.5°.
- The sills are discontinuous and are terminated by steeply dipping high-angle normal or reverse faults.
- Within fault blocks, the sills appear to retain a uniform thickness.
- The faults show readily recognizable geomorphic expressions.

In the following paragraphs the above conclusions will be discussed in more detail.

The most northerly sill, the western half of which is being actively mined (fig. 13), has a minimum thickness of 113 ft (34 m). The sill has been traced in a WNW-ESE direction for about 4,800 ft (1,464 m; fig. 14). On the east end the sill is cut off by a north-northeast-trending fault. On the west end the sill pinches out against the main west-northwest-trending fault that marks the northern extent of the sill and also defines the northern boundary of Silver City Dome (figs. 5, 10, 14). Within the open-pit mine, at approximately the location between drill holes 10–91 and 12–91, the sill is disturbed by a narrow zone of contaminated-looking lamproitic material. Along this zone a small semicircular knob, on the order of 10 ft (3 m) in diameter, consisting of metamorphosed country rock, sticks up through the lamproite sill. This disturbance probably represents a north-northwest-trending fault that extends in a southerly direction and farther to the south separates the 70+ -ft (21+ -m) lamproite sill to the east from the 50+ -ft (15+ -m) sill to the west (fig. 14). The sill dips at an angle of 2°–3° to the north. To the south the sill thins down to a featheredge as the result of the combined effect of erosion and the dip of the sill.

A sill having a thickness of 68–83 ft (21–25 m) is present in three fault blocks in the eastern half of sec. 32 (fig. 14). Even though the thickness does vary, the sill in the fault blocks is believed to be the same sill. The dip of the sill in the fault blocks varies from a few degrees to more than 5°.

In the western half of sec. 32, T. 26 S., R. 15 E., lamproite sills having a thickness 40–64 ft (12–20 m) are present. The greater thickness is found in drill holes to the east and the lesser thickness in drill holes to the west. Either the sill gains in thickness to the east or else two separate sills may be present. However, not enough information is available to decide which is the case. South of drill hole 2–92 (fig. 6), a lamproite sill of similar thickness is found in several drill holes farther to the south and east. However the lamproite sill in this part of the section dips at an angle of 2° to the south. This is the only sill for which good evidence indicates dips in a southerly direction. Also the stratigraphic position of the sill within the sedimentary section differs from that of the sill farther to the north. So, even if this is the same sill, it is evident that a fault exists at the hinge line where the dip changes from north to south.

In the area of sec. 32, T. 26 S., R. 15 E., where we have sufficient drill information, it is apparent that individual sills are broken up and bounded by faults.

Useful information is also obtained from oil-exploration wells (table 4, fig. 10). In the southwestern part of sec. 33, T. 26 S., R. 15 E., four holes have been drilled inside the boundary defining the dome to depths ranging from 621 to 1,515 ft (189–462 m). Various electric logs are available, but it is not possible to recognize lamproite sills on gamma ray, neutron, or other logs. Geological reports, describing the sample cuttings, are available for two of the holes. In the #1 Ecco Ranch drill hole, drilled to a total depth of 1,291 ft (394 m), six lamproite sills were found at depths ranging from 374 to 786 ft (114–240 m), and thickness from 4 to 31 ft (1.2–9 m; table 4). The reported thickness and depth is only a good approximation, because it is difficult to recognize the lamproite in cuttings, unless the person attending the drill hole is familiar with this rock. Mica is quite readily recognized, but to the untrained eye difficult to distinguish from phlogopite. White mica is common in some of the Pennsylvanian sandstones in the section. The Eby 1–33 drill hole was spotted close to the boundary of the dome and drilled to a total depth of 1,515 ft (462 m). In the Eby 1–33 drill hole, two lamproite sills were recognized at depths ra¡nging from 472 to 934 ft (144–285 m) and thickness from 15 to 48 ft (4.5–15 m; table 4). In this drill hole no sample cuttings were recovered above 400 ft (122 m). No obvious correlation seems to be present between the lamproite sills in the two drill holes. Electric logs and one geologic report for five oil-exploration drill holes located close to, but outside, the boundary of the dome were examined. No evidence of lamproite sills occurring in any of the holes is evident.

In the northwestern part of sec. 4, T. 27 S., R. 15 E., six oil-exploration drill holes ranging in depths from 619 to 1,500 ft (189–458 m), are located (table 4). Five geologic reports are available for these drill holes and all document the existence of lamproite sills in Pennsylvanian rocks at depths ranging from 305 to 1,200 ft (93–366 m) and thickness from 4 to 75 ft (1.2–23 m; table 4). Sample cuttings were generally not recovered in the upper parts of the drill holes; hence, additional shallow sills may be present. Again, as in the drill holes to the north, lamproite sills cannot be traced over any distances. Even considering drill holes #1A–4 Eby and #1–4 Eby (table 4), which are less then 20 ft (6 m) apart, the correlation is poor, especially if the thickness of sills within fault blocks is relatively constant. At least two dozen other oil-exploration holes have been drilled in the section. Geophysical logs and some geologic reports are available for these drill holes, but there is no indication that lamproite was encountered in any of these drill holes.

Less drill-hole data are available in sec. 4, T. 27 S., R. 15 E. and sec. 33, T. 26 S., R. 15 E., but the evidence favors a similar interpretation for the occurrence of lamproite sills as in sec. 32, T. 26 S., R. 15 E.

A number of other oil-exploration drill holes have been drilled at Silver City Dome, but lamproite sills have been recognized and recorded in only a few. In the western part of the dome in sec. 31, T. 26 S., R. 15 E., three holes were drilled at the Guess property (fig. 8, table 4). In each of these drill holes, a thick lamproite sill was found near the bottom of the hole at about 900 ft (275 m). In the Guess #1 drill hole, a lamproite sill having a minimum thickness of approximately 100 ft (31 m) occurs at the bottom of the hole. The geological report also mentions some free oil in the lamproite. In the Guess #2 drill hole, another sill, having an approximate minimum thickness of 100 ft (31 m) , is present. Free oil and gas are also reported at this depth in the geological report. The report also notes a contact with bleached (i.e., metamorphosed) sedimentary rock at 920 ft (281 m). The exact location of this drill hole cannot be established, but it is believed to be close to the former drill hole (personal communication with landowner). In the Guess #3 drill hole, a much thinner lamproite sill, having an approximate minimum thickness of 30 ft (9 m), occurs at the bottom of the drill hole.

Because the above three holes bottomed out in lamproite, the true thickness of the sill or sills is not known. The geologist describing the rocks applied different terms to the igneous rock. This is another reason the thickness may not be exactly as reported.

An open-file report by Wagner (1967) dealing with the "geology and mineral resources of Wilson County, Kansas, with special reference to oil and gas resources," shows a cross section involving five drill holes, two of which are outside the boundary defining the dome and three within the southern part of the dome. The two drill holes outside the boundary did not encounter any igneous sills, but the three inside the dome, located in secs. 5 and 6, T. 27 S., R. 15 E., did (fig. 10, table 4). In the Hase No. 1 drill hole completed in 1922, a 190-ft (58-m)-thick lamproite sill was encountered at a depth of 915 ft (279 m; fig. 11). This is by far the thickest sill reported from anywhere in the dome. It is curious that no other sills at shallower depths are reported in this drill hole. The fact that the reported sill is very thick probably played an important role in it being recognized, as opposed to possible thinner sills elsewhere in the drill hole. The Bentley No. 1 drill hole was spotted (fig. 10, table 4) about 1/4 mi (0.4 km) to the southeast. The date of completion of the hole was not recorded and the hole probably was drilled at about the same time as the previous hole. In this drill hole two lamproite sills are reported. The upper one at 910 ft (278 m) is 150 ft (46 m) thick and the lower one at 1,142 ft (348 m) is 13 ft (4 m) thick (fig. 11). In his cross section, Wagner (1967) correlates the thick sill between the two wells and assumes that the sill thins in a southeasterly direction. The third drill hole was spotted 1.5 mi (2.4 km) to the east (fig. 10). In this drill hole, the Young No. 1, four lamproite sills were found, the thickest one being 52 ft (16 m) and closest to the surface (fig. 11, table 4). Wagner (1967) interprets the lowest sill at 1,038 ft (317 m) to be the same as the thick sill in the other two holes thinning in an easterly direction. Wagner (1967) also shows the other sills encountered in the Young No. 1 drill hole to thin laterally.

In light of what we have learned from our drilling and other new data, the thinning of the sills and the correlation shown in the cross section of Wagner (1967; fig. 11) may be open to another interpretation to include possible faulting, unless the behavior of the sills in the southern part of the dome is distinctly different.

Rose Dome

Much less information is available about the occurrence of lamproite at Rose Dome. Several dozen oil exploration holes have been drilled (fig. 9, table 8), but no information on the presence of lamproite sills is available from any of the holes except one. In the #1 Eagle Marvin, drilled in 2001 to a depth

TABLE 8—Drill-hole locations at and near Rose Dome.

Location		**Drill-hole Name**	**T.D. (ft)**
12-26S-15E (1920)	Union Oil Co.	Granite	2807-2929 ft (123 ft)
12-16-15E	C WL NW NE	#1 Drummond	TD 1465
	NW C NE	#1 Drummond	TD 1450
	NW W/2 N/2 NW	#1 Pringle	TD 1465
13-26-15E	NW NE SW	9 Jack Drewer	TD 1295
	C EL W/2 NW	3 Fegan	TD 1289
slate at 667 ft?	C EL W/2 NW	4 Fegan	TD 1339
	C W/2 NW NW	5 Fegan	TD 1357
	NE NW SE	1 Thad Carsons	TD 1671
	C SE SE	1 F. L. Parsen	TD 1280
	SW SW SE	1 Pringle	TD 1315
14-26-15E	NW NE NE	1 State Exc. Bk.	TD 1462
23-26S-15E	SE NE	1 Awalt	TD 1340
	C SL SE	1 Pingrey	TD 1583
	SE SE SE (1,100 ft FSL, 230 ft FEL)	1 Elmer Diver	TD 1120
	SW C NE	1 John Pringle	TD 1265
	SW C NE	1 Pringle	TD 1250
		1 Rose	TD 1679
7-26S-16E	SE NE NE	Ibbetson	TD 1378
	NE SW SE	6 Mathies	TD 814
lamproite?	E of Brush School	Parsons	TD 1068
8-26S-16E	SE C SE	1 Bideau	TD 1365
	NW SE SE	1 Highfill	TD 956
	SW SE NE	Howard #1	TD 1150
	SE cor SE	1 Howard	TD 1157
	NE SE NE (200 ft EL)	2 Howard	TD 1172
	NE SE SE	3 Howard	TD 1338
	NW NW SE	#2 Howard	TD 1144
	NE NE SE	#1 Howard	TD 1146
	SW NW SE	#2 Howard	TD 1170
	S/2 NW SE	#3 Howard	TD 1146
	C NW SE	#4 Harry L. Howard	TD 1195
	NE SE	5 Howard	TD 1130
	W/2 NW	#1 Howard	TD 1359
	NE SE SE	2A Howard	TD 1338
	N/2 NE SE (200 ft FSL, 830 ft FEL)	2 Howard "B"	TD 1174
17-26S-16E	SE NE	Gurnan #1	TD 1226
	C SE	1 Cox Estate	TD 1182
	N/2 N/2 NE (175 ft FNL, 1,495 ft FEL)	1 Seivers	TD 1160
	NE C SW	1 White	TD 1201
18-26S-16E	SW C NE	#1 Cox	TD ?
		#2 Cox	TD 1125
	NW SW SE NE	1 Diver	TD 680
	NE NW SE	1 Diver	TD 1125
	SW C NE	1 Diver	TD 1606
	C NW SE (1980 FSL, 1980 FEL)	#1 Marvin Eagle	TD 964
	El SW SW	2 Thad Parsons	TD 1220
copper sand 960–1000 ft	SE SW SW	1 Thad Parsons	TD 1201
19-26S-16E	C NE SW	1 Eagle	TD 1648
		5 Jackson	TD 876
		6 Jackson	TD 900
		1 Taylor	TD 1200?
	C NE NW	1 Taylor	TD 1250
20-26S-16E	C SW	1 Chandler	TD 1096
	C NW NW	1 Howard	TD 1409
	SE NE NE (1,000 ft FNL, 250 ft FEL)	1 McKinsey	TD 1377
	SE SE	#1 Shotts	TD 1318
23-26S-15E	SE NE	#1 Awalt	TD 1340
	C S/2 SE	#1 Pingrey	TD ?
24-26S-15E	SE SE SE	#1 Elmer Diver	TD 1120
	SW C NE	#1 John Pringle	TD 1265
	SW C NE	#1 Pringle	TD 1250
	?	#1 Rose	TD 1679

of 964 ft (294 m) to evaluate the Pennsylvanian organic-rich rocks for their coalbed-methane potential, a thick lamproite sill was recognized by the geologist (Michael Ebers, personal communication, 2001) attending the well. Based on this information we drilled two more holes in the same section in 2003. Both holes, Eagle 4 and Eagle 5, were spotted on the topographic high in the central part of the dome (fig. 9). It was reasoned that the topographic high might be the surface expression of a more resistant dike in the subsurface along which the lamproite intruded. In both drill holes (appendix 9), a thin (about 5 ft [1.5 m]) lamproite sill was found at a shallow depth below a thin limestone cover. A thicker lamproite sill was encountered at a depth of about 400 ft (122 m).

Some other information on the presence of lamproite is available from five shallow (less than 100 ft [31 m]) drill holes completed in 1964 by the Kansas Geological Survey (fig. 9) on top of the knoll in sec. 13, T. 26 S., R. 15 E. just west of K–75 (Franks et al., 1971). In the deepest drill hole (DDH–3), three thin sills were recognized, while the thickest sill in DDH–4 measured a little over 13 ft (4 m; see appendix 8).

Information obtained from the small number of drill holes that record lamproite sills in the subsurface is not enough to draw any meaningful conclusions about the extent or number of sills present at Rose Dome. However, the morphology of the dome is essentially exactly the same as that of Silver City Dome. Therefore we believe that similar structures will be found at Rose Dome. Both concentric faults paralleling the periphery of the dome as well as radial faults can be expected to influence the distribution of the sills.

Geophysical Studies

The earliest published geophysical study was a radioactive survey conducted in 1948 over Rose Dome using a Geiger counter (Hartenburger, 1959). In the course of this study two traverses were laid out, one trending N20°W and the other N55°E, and passing through the highest part of the dome where an abundance of granite boulders are present. As expected the highest radioactive readings were recorded at the high point on the dome where the granite boulders occur at or near the surface.

Years later a magnetic survey over both Rose and Silver City domes and the surrounding area was carried out by Hambleton and Merriam (1955), using a Ruska vertical magnetometer. Readings over the two domes were taken on a 40-acre spacing. The authors concluded that the magnetometer is a useful tool to map broad geologic structures but could not be used to determine the character and extent of the intrusive igneous rocks. Hambleton and Merriam (1955) show magnetic lows north-northwest of the center of the domes. However, the north-northwesterly trend of the lows does not coincide with the northeasterly structural trend of the domes. This pronounced trend also can be seen in the structure maps on the base of the Plattsburg Limestone and the top of Mississippian rocks included in the publication by Hambleton and Merriam (1955).

During the summer of 1985, a seismic-reflection study was conducted at Silver City Dome (Wojcik, 1986). Two north-south profiles across the dome, offset by 1/4 mi (0.4 km) along the Wilson–Woodson county line, were completed (fig. 10). The 1.5-mi (2.4-km)-long northern profile started 1/2 mi (0.8 km) north of the open-pit mine and continued through the open pit south along the entrance road to the mine at the Woodson–Wilson county line. The 1.25-mi (2-km)-long southern profile started 1/4 mi (0.4 km) to the east and continued south along the county road past the Ecco Ranch headquarters.

The study indicates that Silver City Dome is indeed a structural dome, but the interpretation only allows a rough image of the structure because of its two-dimensional character and because there is a gap between the two profiles (Wojcik, 1986). Wojcik (1986) was able to identify the northern boundary fault, which was proved to exist by drilling, as well as a southern boundary fault. Wojcik (1986) identified additional faults both within as well as outside the dome, but the attitude and precise location of these faults cannot be verified.

Wojcik (1986) was not able to identify lamproite sills, but he concluded that the feeder along which the lamproite was injected into the stratigraphic succession is marked by a central disturbed depression within the dome and bounded by high-angle normal faults. The area Wojcik defines as the central depression is between our drill holes 7–92 to the north and 2–95 to the south (fig. 6) and graphically shown in cross section A–A′ (fig. 17). Drill hole 11–92 (fig. 6), located in the center of the disturbed depression, was completed to a depth of 148 ft (45 m) and has a 53-ft (16-m)-thick lamproite sill at 62 ft (19 m; see appendix 2). Examination of the drill core of this hole shows a normal, nearly flat-lying, undisturbed section of alternating limestone and shale. The two drill holes to the south, 6–95 and 2–95, completed to depths of 76 and 189 ft (23–58 m), respectively, contain no lamproite sills and no disturbed or disrupted rocks (see appendix 3). In drill hole 7–92, completed to 84 ft (26 m), a 57-ft (17-m)-thick lamproite sill occurs at 19 ft (6 m), but in this drill hole the rocks are also undisturbed (see appendix 2). No evidence of a depression exists on the surface as suggested by Wojcik (1986). The results and interpretation of the seismic-reflection study were also presented at a Geological Society of America annual meeting (Wojcik et al., 1986).

The data obtained from the seismic-reflection profile (Wojcik, 1986) were also examined and reprocesssed by Markezich (1985) and Markezich et al. (1988). The study confirmed earlier conclusions (Wojcik, 1986) suggesting that it helped improve the understanding of the structural complexity of the dome and that higher resolution data were needed to identify the location of individual lamproite sills. As part of the study by Markezich et al. (1988), data were collected along several magnetic profiles in the vicinity of the seismic lines, believing that fractured strata often have distinctive magnetic signatures. Additional seismic data also were collected using dynamite as a source to provide more detail of the seismically chaotic zone believed to be the feeder zone for the magma.

Unfortunately none of these studies shows on a topographic map in detail where the interpreted faults exactly occur at Silver City Dome, thus making correlation with data obtained from drilling difficult.

Examination of gravity and magnetic data by Knapp and Adkins–Heljeson (1988) indicates that both Silver City and Rose domes occur at or near the edge of interpreted basement structural features. In the section dealing with structure, reference is made to the strong possibility that northeast-trending faults give the landscape between the two domes its peculiar geomorphology.

Interpretation of the results of an 1,140-ft (300-m)-long seismic-reflection survey conducted in 1996 in the area between the two domes where a northeast-trending fault is suspected to occur was published by Baker et al. (1998; fig. 2). They interpret a stratigraphic offset of a minimum of 50 ft (15 m) on several faults from one end of the profile to the other (fig. 22). At the same time that the seismic survey was conducted, the author identified a linear northeast-trending narrow zone of quartzite a few hundred feet north of the northern end of the seismic line (fig. 2). In 1999 we drilled three holes varying in depth from 79 to 188 ft (24–57m; fig. 2; see appendix 11) on the other side of the road from where the seismic profile was conducted. The results obtained from drilling show no faults along the trace of the seismic line (fig. 23). It is suspected that a northeast-trending fault occurs several hundred yards north of the seismic line (fig. 2), coinciding with the trend of the quartzite. Looking at the morphology of the area, other northeast-trending faults are believed to occur in the vicinity (fig. 2).

The Kansas Geological Survey conducted a vertical seismic profile (VSP) survey in 1999 to evaluate the method to map individual lamproite sills in the subsurface. In this experiment, the data were recorded at drill hole 2–98 (fig. 6) using a 20–400-Hz 2.5-sec sweep by the IVI Minivib. The source was located west of the drill hole using 3-C downhole phones. The data were processed using the VSP product of ProMAX version 7. Severe static problems existed within the data set. Several techniques were applied to correct this situation, but it was impossible to recognize the 56-ft (17-m)-thick lamproite sill that occurs at a depth of 70 ft (21 m)within a limestone unit.

Davis (2003) conducted a ground-magnetic survey at Rose Dome, trying to locate lamproite feeder dikes and possible sills in the subsurface as well as to delineate the boundary of the physiographic feature. Even though no conclusive evidence could be established for the occurrence of lamproite in the subsurface, Davis (2003) believes that a centrally located west-to-east high-low anomaly may represent lamproite sills in the subsurface or a feeder dike for the intrusion. Davis (2003) speculates that other anomalies associated with Rose Dome may indicate faulting along the outer edge of the dome.

In August 1984, Hubbard (unpublished data) of Chevron Resources Co. carried out a conductivity survey at Silver City Dome. Nine approximately north-south traverses were run across the lamproite sill in the northern part of sec. 32 and adjoining portions of secs. 29 and 33, T. 26 S., R. 15 E. (fig. 24). The changes in measured values relate to contacts between stratigraphic units, including lamproite sills, but also reflects changes in vegetation, the presence of creeks, and areas affected by mining.

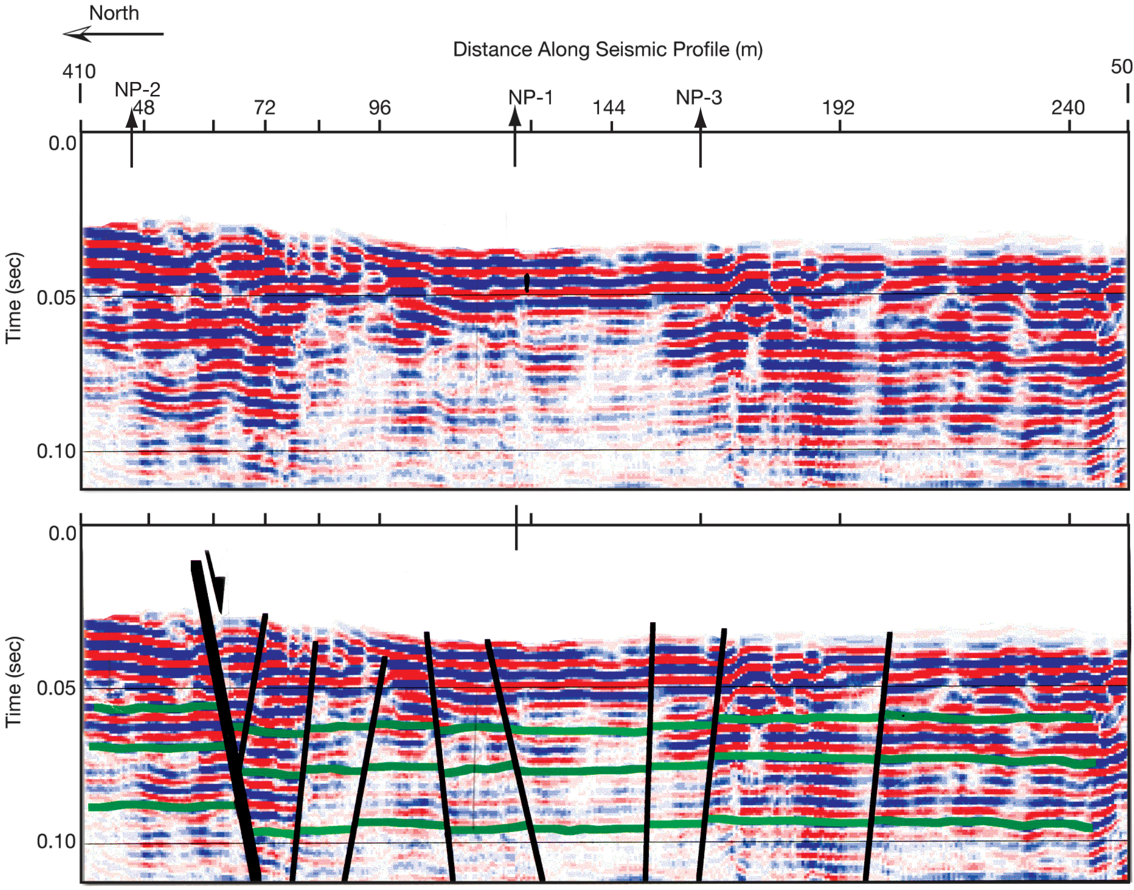


FIGURE 22—Interpretation of the seismic reflection profile (Baker et al., 1998), the location of which is shown in fig. 2.

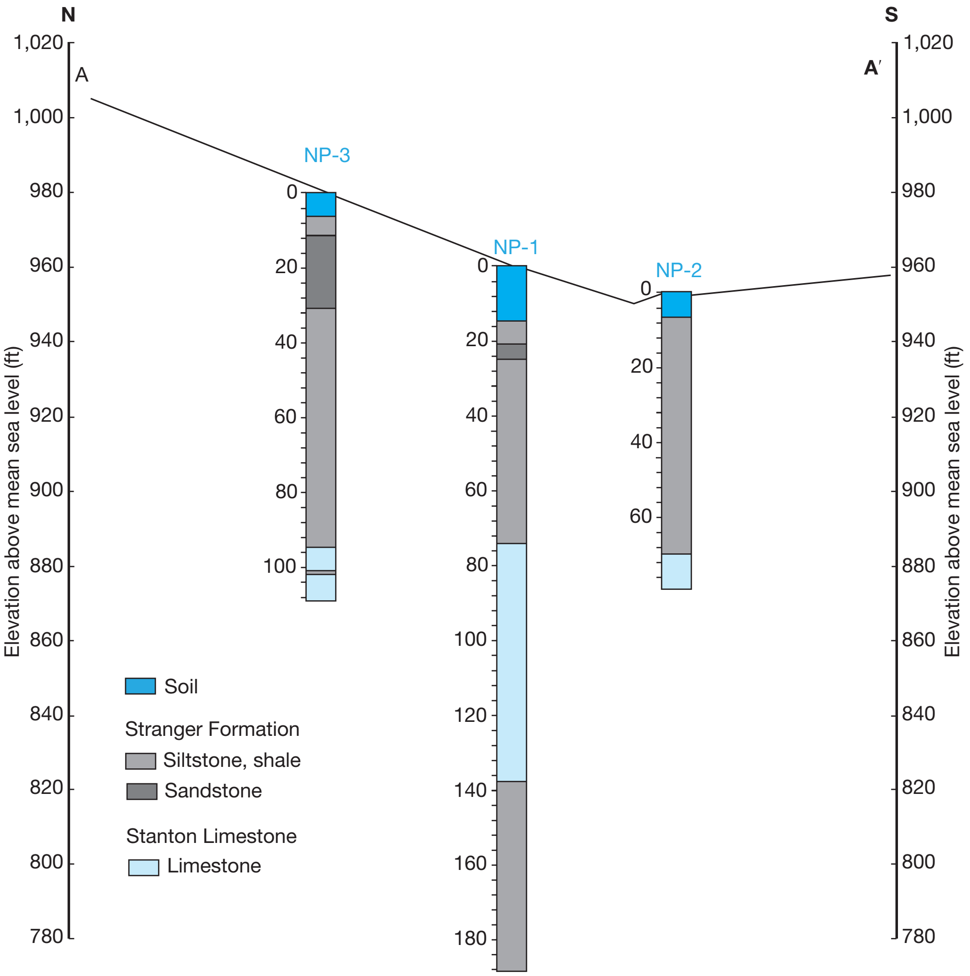


FIGURE 23—South-north cross section through drill holes NP-1-3 on the other side of the road where the seismic-reflection survey was conducted.

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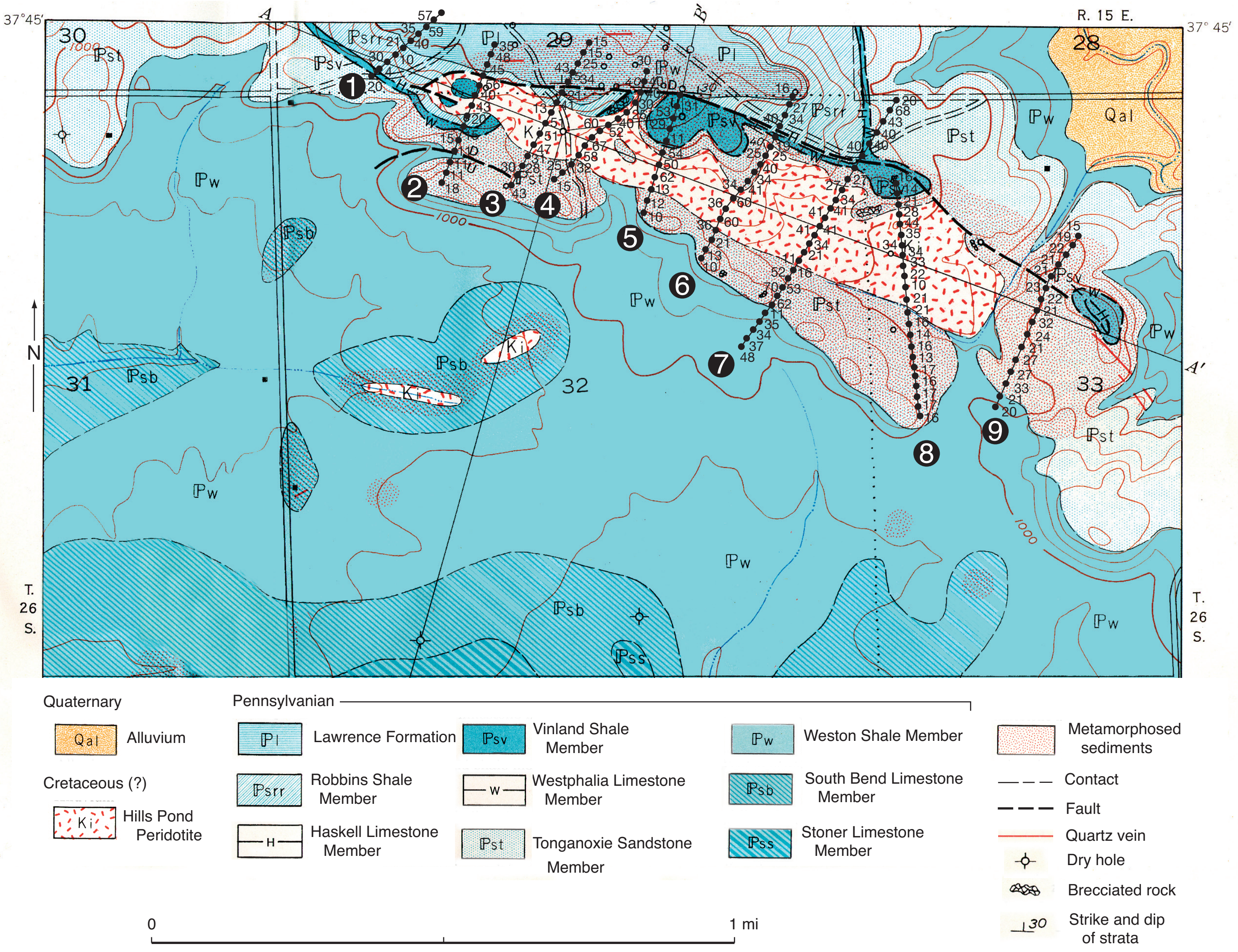

FIGURE 24—Results of a conductivity survey at the Micro-Lite LLC mine site in the northeastern part of Silver City Dome by Hubbard (1984, unpublished).

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Appendix 1—Brief description of core from drill holes 1–91 through 16–91 together with graphic logs of the lithologies encountered.

Micro-Lite Holes – 1991

CH–1–91

13 ft 2 inches	Quartzite, some soft material
13 ft 2 inches– 19 ft 2 inches	Sharp contact with weathered lamproite; good core recovery
19 ft 2 inches– 48 ft 2 inches	Poor recovery throughout; weathered lamproite
48 ft 2 inches– 53 ft 2 inches	Good lamproite with phlogopite
53 ft 2 inches– 58 ft 2 inches	Lamproite darker and fresher than above
58 ft 2 inches– 58 ft 5 inches	Contact between weathered and fresh lamproite
58 ft 5 inches– 107 ft 5 inches	Lamproite
107 ft 5 inches– 111 ft 8 inches	Lamproite
111 ft 8 inches– 112 ft	Slate parting 1 inch
112 ft–114 ft 4 inches	Lamproite
114 ft 4 inches– 114 ft 6 inches	Quartzite and slate
114 ft 6 inches– 116 ft	Lamproite with quartzite stringers
116 ft–118 ft	Bedded quartzite
118 ft–128 ft	Hornfels and quartzite; good recovery

CH–2–91

18 ft	No record
18 ft–37 ft 8 inches	Weathered lamproite
37 ft 8 inches– 44 ft 9 inches	Hard, pinkish lamproite
44 ft 9 inches–47 ft	Hard, banded slate and quartzite
47 ft–57 ft	Slate with minor quartzite

CH–3–91

14 ft 5 inches	Slate and quartzite
14 ft 5 inches– 60 ft 1 inch	Weathered lamproite; contact at bottom
60 ft 1 inch–61 ft 1 inch	Fresh and hard lamproite
61 ft 1 inch– 127 ft 5 inches	Lamproite
127 ft 5 inches– 137 ft 5 inches	Shale

CH–4–91

(located approximately 240’ north of CH-3)

31 ft	Gray to gray-brown, soft, weathered shale; some intervals have many iron-stained fractures
31 ft–46 ft 5 inches	Soft, blue-gray shale

CH–5–91

5 ft	Overburden
5 ft–20 ft	Dark, olive, clayey weathered lamproite
20 ft–20 ft 5 inches	Thin shale
20 ft 5 inches–40 ft	Dark, very green weathered lamproite
40 ft–57 ft	Fresh lamproite, hard to sample; still will not drill easily; water (4 inches) at 48 ft
57 ft–57 ft 4 inches	Hard-baked shale
57 ft 4 inches– 62 ft 3 inches	Fresh lamproite
62 ft 3 inches– 64 ft 6 inches	Shale
64 ft 6 inches– 66 ft 4 inches	Lamproite; All contacts sharp, especially bottom; shale is quite hard
66 ft 4 inches– 67 ft 1 inch	Lamproite; sharp contact with below
67 ft 1 inch– 77 ft 5 inches	Shale

CH–6–91

(330 ft east of fence, 35 ft to 45 ft north of fence)

10 ft	Reddish clay, gray shale
10 ft–26 ft	Gray to blue-gray shale

CH–7–91

(Located in pit near contact; 180 ft south of corner post)

33 ft 7 inches	Weatherd lamproite; few hard stringers; rock harder and freshwater below 24 ft
33 ft 7 inches–67 ft	Fresh lamproite

CH–8–91

(Bottom of pit)

26 ft 2 inches	Hard lamproite
26 ft 2 inches– 36 ft 8 inches	Shale

CH–9–91

18 ft	Weathered lamproite
18 ft–39 ft 8 inches	Blue-gray to gray shale

CH–10–91

13 ft	“Fill material”
13 ft–14 ft	Hard lamproite stringer
14 ft–20 ft 5 inches	Gumbo
20 ft 5 inches–23 ft	Hard lamproite
23 ft–30 ft 4 inches	Sandstone
30 ft 4 inches–48 ft	Gray to tan sandstone, interbedded shale

CH–11–91

(West end of the dike of upper pond)

7 ft	Overburden
7 ft–14 ft 4 inches	Black shale and siltstone
14 ft 4 inches–14 ft 6 inches	Quartzite stringer
14 ft 6 inches–23 ft 4 inches	Shale as above
23 ft 4 inches–24 ft 4 inches	Coaly bed
24 ft 4 inches–28 ft 4 inches	Shale as above

CH–12–91

(Just north of lower pond)

13 ft 4 inches	Weathered lamproite; last 0.5 ft fresher
13 ft 4 inches–44 ft	Fresh lamproite
44 ft–45 ft 6 inches	Contact zone with quartzite and metamorphics
45 ft 6 inches–51 ft 4 inches	Metamorphics
51 ft 4 inches–55 ft 8 inches	Lamproite sill
55 ft 8 inches–58 ft 3 inches	Shale and siltstone

CH–13–91

34 ft 8 inches	Weathered lamproite
34 ft 8 inches–57 ft 6 inches	Fresh lamproite
57 ft 6 inches–67 ft 6 inches	Metamorphosed hard shale and siltstone. The last 0.5 ft are especially altered. May be another thin sill below this as in CH–12–91.

CH–14–91

63 ft 8 inches	Shale
63 ft 8 inches–72 ft 2 inches	Stanton Limestone
72 ft 2 inches–79 ft	Lamproite sill
79 ft–188 ft	Limestone, shale, limestone

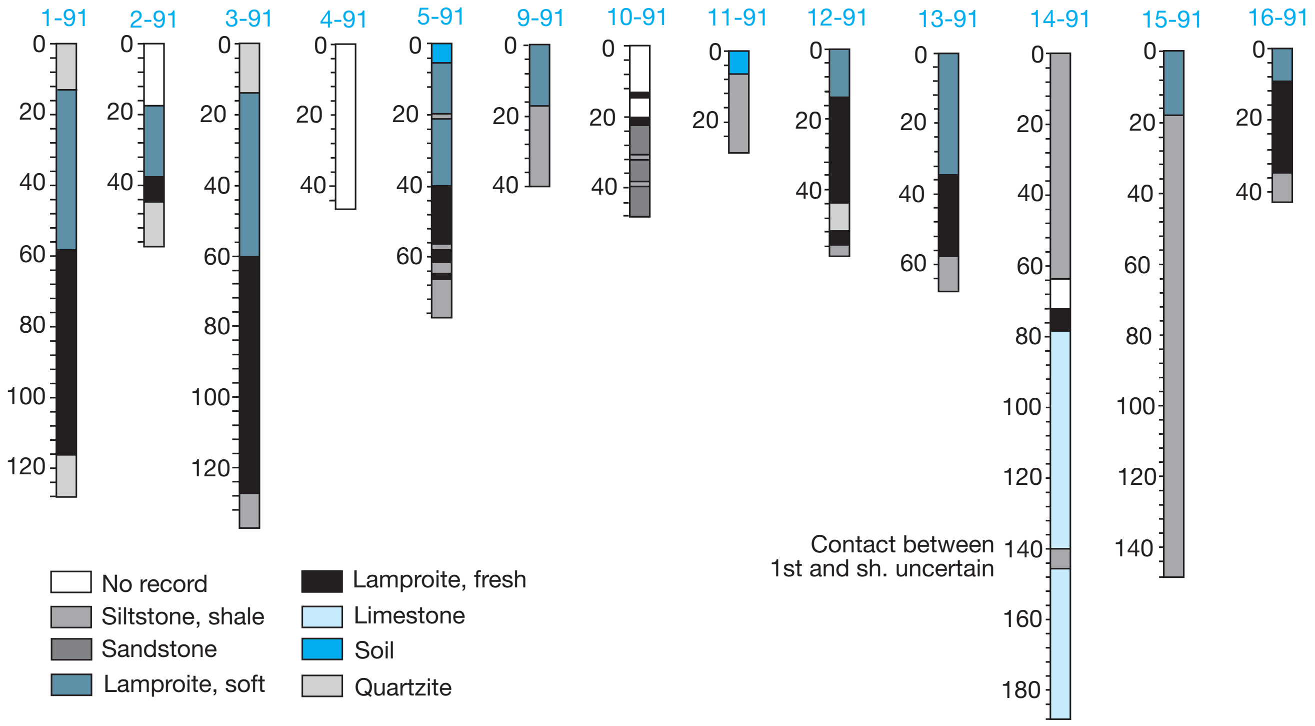
CH–15–91

15 ft	Honey-colored lamproite
15 ft–18 ft	Lamproite redder
18 ft–73 ft	Gray to black shale
73 ft	Lost circulation, no evidence of fracturing
73 ft–148 ft 2 inches	Gray to black shale. No Stanton Limestone in this hole…curious

CH–16–91

(Located in center of east end of east pit)

8 ft 8 inches	Fresh, honey-colored lamproite
8 ft 8 inches–35 ft	Lamproite
35 ft–43 ft	Gray to black shale



APPENDIX FIGURE 1.1—Graphic representation of drill core from Micro-Lite holes 1-91 to 5-91 and 9-91 to 16-91.

Appendix 2—Brief description of core from drill holes 1–92 through 12–92 together with graphic logs of the lithologies encountered.

CH 1–92 Elevation unknown

0	1.0 ft	Soil
1.0 ft	8.0 ft	Quartzite, hard, brittle
8.0 ft	49.0 ft	Rock is mostly a hard siltstone, but fine-grained sandstone is common. Rock is commonly fractured. Dips up to 45° are noted at a depth of about 40 ft, where the rock is also brecciated
49.0 ft	57 ft 5 inches	Poor-quality lamproitic material
57 ft 5 inches	103 ft 8 inches	Dark-gray shale and lighter-colored siltstone, not altered
103 ft 8 inches	115.0 ft	Limy shale or siltstone with some fossiliferous limestone at the top

CH 2–92 Elevation 970 ft

0	5 ft 2 inches	Soil
5 ft 2 inches	27 ft 4 inches	Soft lamproite
27 ft 4 inches	51 ft 1 inches	Fresh, hard lamproite
51 ft 1 inches	118 ft 4 inches	Limestone. Oolitic near the top. Rock is partially mottled, partially dark gray. Also some pyrite. Rock is dark and shaly at about 73 feet. Below that the limestone is clean and stylolitic

CH 3–92 Elevation 974 ft

0	5.0 ft	Soil
5.0 ft	11 ft 1 inches	Gray shale
11 ft 1 inches	15 ft 1 inches	Limestone. Lower 4 inches is oolitic
15 ft 1 inches	61 ft 10 inches	Lamproite. Fresh and hard, except for a few feet near the top
61 ft 10 inches	69 ft 5 inches	Limestone. A 2 ft 9 inch transition zone from lamproite to limestone at the top

CH 4–92 Elevation 974 ft

0	22 ft 5 inches	Used roller bit. No recovery
22 ft 5 inches	33 ft 5 inches	Gray shale
33 ft 5 inches	37 ft 5 inches	Light-gray limestone, fossiliferous
37 ft 5 inches	41 ft 10 inches	Lamproite, fresh, hard
41 ft 10 inches	42 ft 3 inches	Limestone, oxidized at the contact
42 ft 3 inches	78 ft 4 inches	Lamproite
78 ft 4 inches	82 ft 5 inches	Lamproite-limestone mix in a transition zone
82 ft 5 inches	90 ft 11 inches	Limestone, fossiliferous. Some thin, dark-gray shale interbeds. Limestone lighter gray in the upper part, turning dark below

CH 5–92 Elevation 990 ft

0	21 ft 9 inches	Casing, no recovery
21 ft 9 inches	60 ft 9 inches	Gray shale
60 ft 9 inches	65 ft 2 inches	Limestone
65 ft 2 inches	107 ft 10 inches	Lamproite, fresh, hard
107 ft 10 inches	128 ft 0 inches	Limestone and some limy shale

CH 6–92 Elevation 975 ft

0	14 ft 2 inches	Casing, no recovery
14 ft 2 inches	25 ft 9 inches	Limestone, dark. Shaly in places
25 ft 9 inches	75 ft 10 inches	Lamproite
75 ft 10 inches	85 ft 4 inches	Limestone, stylolitic. Top 2 ft is altered. Mottled light- and dark-gray limestone lower down. Clean limestone at the bottom

CH 7–92 Elevation 983 ft

0	14 ft 4 inches	Casing. No recovery
14 ft 4 inches	19 ft 4 inches	Limestone, oolitic near lower contact
19 ft 4 inches	23 ft 1 inches	Soft lamproite
23 ft 1 inches	76 ft 2 inches	Lamproite, fresh, hard
76 ft 2 inches	84 ft 0 inches	Limestone

CH 8–92 Elevation 1000 ft

0	16 ft 5 inches	Casing. No recovery
16 ft 5 inches	67 ft 3 inches	Gray shale turning dark below 57 ft 6 inches
67 ft 3 inches	70 ft 3 inches	Limestone, slightly altered
70 ft 3 inches	126 ft 2 inches	Lamproite, fresh, hard
126 ft 2 inches	135 ft 9 inches	Limestone, oolitic near the top

CH 9–92 Elevation 980 ft

0	4 ft 10 inches	Soil
4 ft 10 inches	11 ft 5 inches	Limestone. Oolitic between 8 ft 8 inches and 9 ft 8 inches
11 ft 5 inches	21 ft 8 inches	Lamproite, soft
21 ft 8 inches	56 ft 8 inches	Lamproite, hard, dark. The top 10 ft or so is relatively soft even though it is dark colored
56 ft 8 inches	78 ft 9 inches	Limestone. The top 5 ft is quite altered. Below that the limestone is fossiliferous, mostly dark colored and shaly in places

CH 10–92 Elevation 988 ft

0	6 ft 7 inches	Soil
6 ft 7 inches	30 ft 2 inches	Limestone. Most of it light colored and crystalline, but in places it is dark, shaly, and fossiliferous. The lower 2 ft 2 inches is altered
30 ft 2 inches	72 ft 4 inches	Fresh, dark lamproite
72 ft 4 inches	98 ft 11 inches	Limestone. Contact with limestone is sharp, but limestone is altered to 74 ft 8 inches

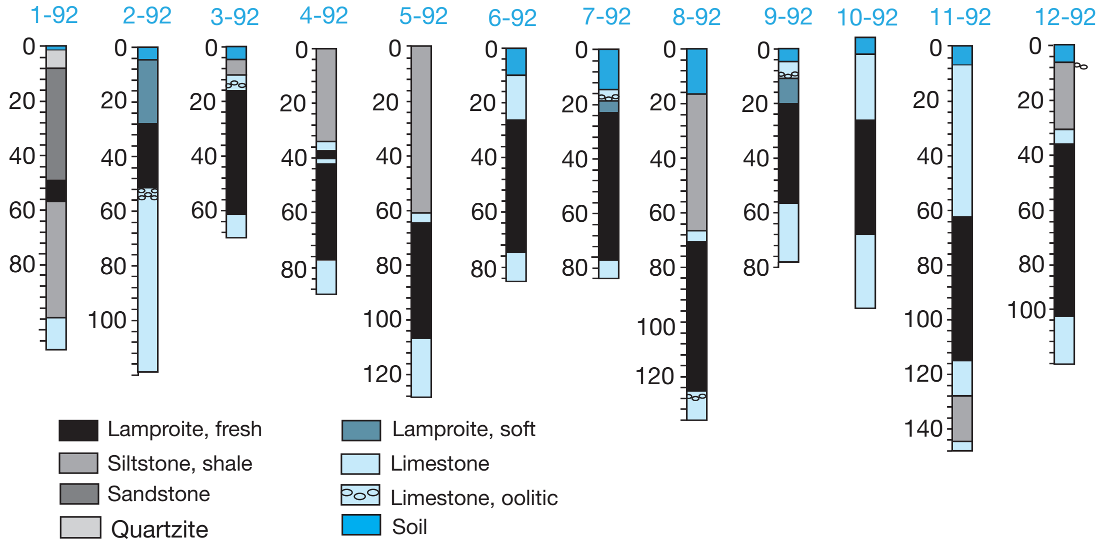
CH 11–92 Elevation 985 ft

0	7 ft 9 inches	Soil
7 ft 9 inches	61 ft 7 inches	Limestone. Alteration is apparent below 48 ft
61 ft 7 inches	115 ft 3 inches	Lamproite, fresh, hard
115 ft 3 inches	128 ft	Limestone
128 ft 0	144 ft 6 inches	Dark shale. The rock is laminated and has irregular, thin, calcareous lenses
144 ft 6 inches	148 ft 1 inch	Limestone. Rounded to elongate calcite crystals in a carbonate matrix (grainstone). Very distinctive rock

CH 12–92 Elevation 990 ft

0	6 ft 9 inches	Soil
6 ft 9 inches	31 ft 4 inches	Shale, gray, weathered near the top. Changes to black, fissile shale at about 8 ft
31 ft 4 inches	35 ft 8 inches	Limestone. The change from shale to limestone is gradual. Limestone is silty and fossiliferous
35 ft 8 inches	99 ft 4 inches	Lamproite, hard, dark
99 ft 4 inches	116 ft 5 inches	Limestone. Shaly, fossiliferous near the contact. Below alternating clean crystalline and dark-mottled shaly limestone

Total footage—1,269 ft Total footage for the 1990–91 season—1,199 ft Grand total drilled under grant #5073—2,468 ft



APPENDIX FIGURE 2.1—Graphic representation of drill core from holes 1-92 to 12-92.

Appendix 3—Brief description of core from drill holes 1–95 through 6–95 together with graphic logs of the lithologies encountered.

Core hole 1–95 Elevation 1,095 ft (north rim of east pit)

0 ft	3.0 ft	Metamorphosed shale and sandstone
3.0 ft	20 ft 9 inches	Mostly lamproite with intermixed shale
20 ft 9 inches	29 ft 9 inches	Weathered lamproite. Recovered only 6 ft
29 ft 9 inches	39 ft 9 inches	Recovered 7 ft of weathered lamproite with good phlogopite content
39 ft 9 inches	44 ft 9 inches	Recovered 32 inches of coarse lamproite
44 ft 9 inches	50 ft 0 inches	Recovered 5 ft of coarse lamproite. Rock becomes fresher and more dark minerals appear. At 47 ft 10 inches a 35° dipping, 2-inch fracture filled with hard material
50 ft 0 inches	59 ft 9 inches	Weathered lamproite to 51 ft 10 inches, fresh below
59 ft 9 inches	69 ft 9 inches	Fresh lamproite
69 ft 9 inches	79 ft 9 inches	Mostly fresh lamproite, except for some thin zones of weathered lamproite, probably along fractures. Lamproite becomes more weathered near the base and the phlogopite content decreases
79 ft 9 inches	89 ft 9 inches	Down to 80 ft 9 inches soft, dark lamproite, grading into harder, darker lamproite with decreasing phlogopite content to 82 ft 4 inches. Contact with contact metamorphosed dark-gray to black shale containing fractures filled with carbonate down to 89 ft 2 inches
89 ft 9 inches	99 ft 9 inches	Down to 90 ft black laminated shale with carbonate-filled fractures. To 91 ft 4 inches a contact-brecciated zone with mixed metamorphic shale clasts and lamproitic material with low phlogopite content, with increasing lamproite material to 96 ft 1 inch. Metamorphosed shale to 97 ft 8 inches, followed by fossiliferous, dark limestone to 99 ft. Below this black, fossiliferous shale
99 ft 9 inches	109 ft 9 inches	Mostly black, laminated, fossiliferous shale. From 107 ft 10 inches to 108 ft 8 inches a greenish-colored, brecciated, fossiliferous limestone seam
109 ft 9 inches	119 ft 9 inches	Down to 111 ft 3 inches a mottled-green shale with pinkish-white irregular limestone clasts. Green-gray to maroon shale to T.D.

Core hole 2–95 Elevation 985 ft

0	20 ft 4 inches	Soil and limestone. Set casing.
20 ft 4 inches	29 ft 0 inches	Fractured, stylolitic, moderately fossiliferous, light-gray to brown limestone
29 ft	39 ft	Limestone as above to 34 ft 4 inches, where it becomes a shaly limestone or limy, dark-gray shale, alternating with thin beds of light-gray limestone and dark-gray shale
39 ft	49 ft	Alternating beds of dark-gray shale and gray limestone, slightly oolitic. At 41 ft 9 inches it grades into a laminated gray shale with oolitic limestone clasts. At 45 ft it becomes an oolitic limestone, which is stylolitic near the bottom of the interval
49 ft	59 ft	Stylolitic limestone with intermittent thin wispy shale partings
59 ft	69 ft	Light-gray limestone, stylolitic, fossiliferous. Brown colored in some places
69 ft	79 ft	Limestone as above. At 76 ft 1 inch a 2-inch dark-gray shale interval. Also 2 inches of black shale at the base with pyrite mineralization
79 ft	89 ft	Down to 79 ft 11 inches same as above, grading into a dark-gray laminated shale
89 ft	99 ft	Shale as above
99 ft	109 ft	Shale as above becoming fossiliferous near the bottom
109 ft	119 ft	Top 8 ft as above, changing into a light-brown, fossiliferous limestone
119 ft	129 ft	Limestone as above, but quite fractured. Some shale partings
129 ft	139 ft	Limestone as above. Minor shale partings
139 ft	149 ft	Same as above
149 ft	159 ft	Same as above
159 ft	169 ft	Same as above, but a few more shale partings
169 ft	179 ft	Same as above down to 174 ft 5 inches, becoming very shaly with carbonate clasts and fossil fragments for about 4 inches.Then grades into a dark shaly limestone, very fossiliferous. Some oolites around 177 ft 2 inches. Below this it becomes a light-gray, fossiliferous limestone
179 ft	189 ft	Dark-gray shaly limestone down to 179 ft 9 inches, grading into a dark-gray laminated shale to T.D.

Core hole 3–95 Elevation 1,058 ft

0	8 ft 5 inches	Casing in soil and shale
8 ft 5 inches	18 ft	Alternating thin wispy beds of shale and brownish sandstone. Some limestone interbeds
18 ft	24 ft 5 inches	Alternating light-gray to brown, oxidized, siltstone and sandstone interbedded with dark-gray shale

24 ft 5 inches	28 ft 7 inches	Mostly siltstone with dark-gray shale stringers
28 ft 7 inches	38 ft	Rock mostly as above. Upper part has high-angle, oxidized, healed fractures filled with light-colored material
38 ft	48 ft	Dark-gray to black laminated shale
48 ft	58 ft	As above
58 ft	68ft	As above. More high-angle fractures around 67 ft 11 inches
68 ft	78 ft	Fractured shale as above
7 ft	88 ft	As above
88 ft	98 ft	Black, laminated silty shale. Beds dipping slightly
98 ft	108 ft	As above
108 ft	118 ft	As above. Fractured in places
118 ft	128 ft	As above, but less silty and fractured
128 ft	137 ft 11 inches	Fissile gray shale
137 ft 11 inches	147 ft 11 inches	As above. Calcite-filled fractures
147 ft 11 inches	157 ft 9 inches	Fractured, fissile gray shale
157 ft 9 inches	168 ft	Black fissile shale. Many bedding-parallel, calcite-filled fractures, fewer fractures at higher angles. At 163 ft 9 inches an 8-inch brecciated limestone bed
168 ft	178 ft	Black fissile shale. Calcite-filled fractures less abundant
178 ft	187 ft 9 inches	Shale down to 179 ft 5 inches, changing gradually to limestone. At 182 ft 2 inches igneous material intrudes along a high-angle fault into the limestone. At 183 ft 1 inch greenish-brown igneous material, possibly containing shale particles. At 184 ft 4 inches intrusive contact with limestone. Limestone to 185 ft 2 inches. Below this more igneous material
187 ft 9 inches	195 ft 7 inches	Igneous material down to194 ft 6 inches. The material is not good lamproite and is contaminated with country rock. Below this limestone impregnated with igneous material. Some phlogopite
195 ft 7 inches	205 ft 10 inches	Down to 197 ft 7 inches mixed limestone and igneous material. Below mixed limestone and gray-green shale. Some limestone clasts in the shale and some shale stringers in the limestone
205 ft 10 inches	215 ft 10 inches	Down to 208 ft 6 inches clean, fossiliferous limestone. Below alternating limy shale and shaly limestone
215 ft 10 inches	225 ft 10 inches	As above down to 224 ft 5 inches changing into clean limestone
225 ft 10 inches	236 ft 1 inch	Fossiliferous, stylolitic clean limestone. Appears to be brecciated and recrystallized
236 ft 1 inch	246 ft 1 inch	As above. Porosity developed in lower 4 ft
246 ft 1 inch	256 ft 3 inches	Porous, clean limestone
256 ft 3 inches	266 ft 4 inches	As above
266 ft 4 inches	276 ft 5 inches	Mixed fossiliferous gray limestone and dark-gray limy shale. Shale irregularly intermixed with the limestone. Last 6 inches good limestone
276 ft 5 inches	279 ft 7 inches	Limestone as above. Vuggy near the bottom
279 ft 7 inches	289 ft 10 inches	Good fossiliferous, stylolitic limestone
289 ft 10 inches	299 ft 9 inches	As above
299 ft 9 inches	309 ft 11 inches	As above
309 ft 11 inches	329 ft 10 inches	Mixed, fossiliferous limestone and shaly limestone. Shale as irregular patches and stringers throughout
329 ft 10 inches	340 ft	Limestone becomes more shaly, especially the last 4 ft 6 inches. Clasts of limestone floating in shale matrix
340 ft	349 ft 8 inches	Down to 343 ft 8 inches as above. Below that gray shale

Core hole 4–95 Elevation 1,008 ft

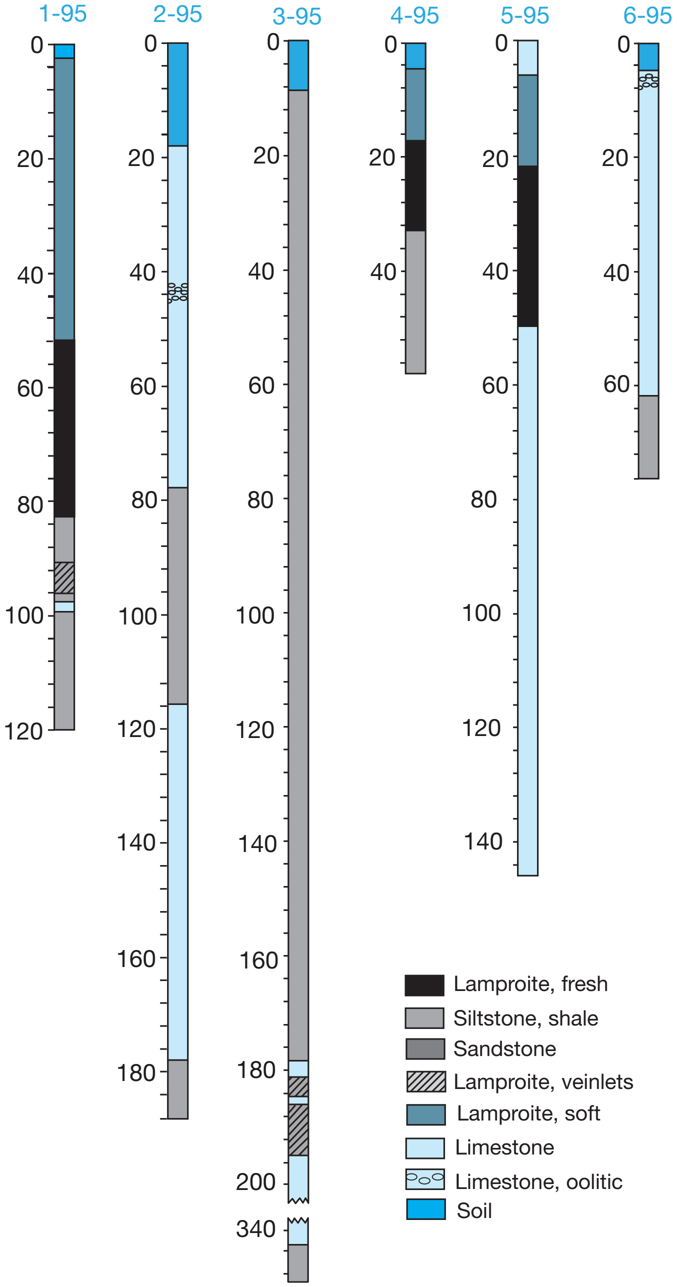
0 ft	7 ft	Soil. Maybe slightly less
7 ft	14 ft 4 inches	Weathered lamproite, recovered 3 ft 2 inches
14 ft 4 inches	17 ft 4 inches	Weathered lamproite, recovered 1 ft 10 inches
17 ft 4 inches	22 ft 4 inches	Down to 17 ft 9 inches weathered lamproite, becoming increasingly more fresh below. Recovered 4 ft 9 inches
22 ft 4 inches	27 ft 4 inches	Fresh coarse lamproite. Recovered 4 ft 11 inches
27 ft 4 inches	37 ft 4 inches	Down to 31 ft 4 inches good fresh lamproite. Transition zone down to 33 ft 4 inches. Slate below
37 ft 4 inches	41 ft 9 inches	Mostly slate, but quartzitic in places
41 ft 9 inches	47 ft 2 inches	Mostly slate containing high-angle fractures
47 ft 2 inches	57 ft 2 inches	Much the same as above, but less altered towards the bottom

Core hole 5–95 Elevation 974 ft

0 ft	9 ft 6 inches	Casing. Soil and lamproite
9 ft 6 inches	11 ft 6 inches	Weathered lamproite. Recovered 6 inches
11 ft 6 inches	15 ft	Weathered lamproite. Recovered 6 inches
15 ft	17 ft	Weathered lamproite. Recovered 8 inches
17 ft	22 ft	Weathered lamproite, slightly fresher and darker towards the bottom. Contact with fresh lamproite at 22 ft 10 inches. Fresh lamproite below. Recovered 2 ft
22 ft	27 ft	Fresh lamproite
27 ft	37 ft	Fresh lamproite
37 ft	47 ft	Fresh lamproite. Recovered 9 ft. Rock is very fractured and contains numerous zones (up to 2 inches thick) where the rock is ground up and smeared. The micas have a white appearance on the fracture surfaces. Secondary calcite is also common
47 ft	57 ft	Down to 51 ft 2 inches fresh lamproite, followed by a 10-inch transition zone to altered limestone, 18 inches thick. This changes to shaly limestone and limestone below. Rock quite fractured. Nice pyrite in the transition zone
57 ft	67 ft	Top part consists of 1 inch of fresh lamproite, followed by 2 ft 7 inches of small limestone clasts floating in a darker, silty limestone, which changes to a clean limestone with some silty limestone wisps. Then 1 ft 11 inches of medium-gray fossiliferous limestone, followed by light-gray fossiliferous limestone to the bottom of the interval
67 ft	73 ft	Limestone as above
73 ft	77 ft	Very fossiliferous, dark, silty limestone
77 ft	87 ft	Top 1 ft 3 inches as above, followed by light-gray, dense limestone with progressively more coarse, secondary calcite. The rock is very punky for the last 1 ft 4 inches
87ft	96 ft 7 inches	Light-gray limestone. Lots of secondary calcite and secondary porosity
96 ft 7 inches	106 ft 7 inches	Limestone as above
106 ft 7 inches	116 ft 7 inches	Limestone as above
116 ft 7 inches	126 ft 6 inches	Limestone less punky and less secondary porosity. Stylolitic. Bottom 2 ft 8 inches is a darker, fossiliferous, silty limestone
126 ft 6 inches	136 ft 4 inches	Down to 132 ft 10 inches silty limestone as above, changing into a fossiliferous grainstone (Individual grains set in a matrix)
136 ft 4 inches	146 ft 4 inches	Limestone as above

Core hole 6–95 Elevation 985 ft

0ft	6 ft	Soil
6 ft	16 ft	Top 3 ft 4 inches oolitic limestone. Oolitis are oxidized. Followed by 5 inches of broken-up limestone. Then 10 inches of rusty limestone and 1 ft 7 inches of clean dense limestone. Lower 2 ft 1 inch is alternating gray, silty limestone and cleaner, gray limestone which occurs as irregular patches and stringers. Recoverd 8 ft 4 inches
16 ft	18 ft	Limestone as above
18 ft	28 ft	First 4 ft as above, followed by 1 ft 3 inches of predominantly limestone with some shale interbeds. Then 3 ft 2 inches of gray, fossiliferous, silty limestone. Lower 11 inches is a gray, dense limestone
28 ft	38 ft 2 inches	Clean, stylolized limestone
38 ft 2 inches	48 ft 3 inches	First 4 ft 6 inches as above, followed by the same rock, but quite porous. The pores are filled with iron-rich minerals
48 ft 3 inches	58 ft 5 inches	First 4 ft 4 inches as above, followed by dense, fossiliferous limestone
58 ft 5 inches	68 ft 9 inches	First 4 ft 9 inches as above. Shaly intervals appear and become more prominent towards the bottom. Below this gray shale
68 ft 9 inches	76 ft 2 inches	Good gray shale



APPENDIX FIGURE 3.1—Graphic representation of drill core from holes 1-95 to 6-95.

Appendix 4—Brief description of core from drill holes 1–97 through 12–97 together with graphic logs of the lithologies encountered.

Core hole 1-97 Elevation 1,005 ft

0 ft	15 ft 8 inches	Set casing. Soil to about 6 ft, below slightly altered alternating shale and sandstone slightly metamorphosed.
15 ft 8 inches	18 ft 2 inches	Top 17 inches is a gray limy siltstone or silty limestone with a couple of thin black shale beds grading into a laminated black shale which shows a hint of being metamorphosed.
18 ft 2 inches	28 ft 3 inches	Laminated black shale. Fine silty or sandy irregular beds in a few places. The last 5 ft or so probably better called a siltstone. Rock is quite hard.
28 ft 3 inches	38 ft 1 inch	Laminated black shale, silty. Quite hard. Very thin white calcite veinlets cutting through are not uncommon.
38 ft 1 inch	48 ft 2 inches	Black shale. Very uniform. Probably silty. Looks black when wet, but more medium gray when dry.
48 ft 2 inches	58 ft 2 inches	Gray silty shale. A number of limy?, light-colored stringers in the top 2 ft 6 inches.
58 ft 2 inches	68 ft 2 inches	As above.
68 ft 2 inches	77 ft 11 inches	Recovered gray silty shale
77 ft 11 inches	88 ft	As above
88 ft	98 ft	As above
98 ft	108 ft	As above
108 ft	117 ft 9 inches	As above
117 ft 9 inches	128 ft	Gray shale. Some high-angle fractures
128 ft	136 ft 2 inches	As above
136 ft 2 inches	140 ft 3 inches	As above
140 ft 3 inches	147 ft 10 inches	As above
147 ft 10 inches	152 ft 2 inches	Shale as above
152 ft 2 inches	157 ft 3 inches	Shale as above
157 ft 3 inches	163 ft 4 inches	Shale as above. Many bed-parallel and steep fractures. Bed parallel fractures filled with calcite(?) approx. 1 mm thick. Two 1-inch silty units in the interval. At bottom a beautiful preserved gastropod (pyritized).
163 ft 4 inches	167 ft 10 inches	First 6 inches shale, changing quickly to limestone, small pores.
167 ft 10 inches	177 ft 11 inches	Last 4 inches limestone pellets-clasts (rounded) mixed with shale. Upper 6 ft mostly clean fossilized limestone.

Core hole 2–97 Elevation 1,012 ft

0 ft	12 ft 6 inches	Weathered soft lamproite, minor soil
12 ft 6 inches	14 ft 6 inches	Weathered lamproite. Good phlogopite content.
14 ft 6 inches	16 ft 6 inches	Same weathered product
16 ft 6 inches	18 ft 6 inches	As above
18 ft 6 inches	20 ft 6 inches	As above, but material gets a little harder
20 ft 6 inches	22 ft	Honey-brown lamproite. Getting fresher. Good amount (20–25%) fine phlogopite.
22 ft	25 ft	As above.
25 ft	28 ft	As above.
28 ft	31 ft	Rock becomes quite fresh.
31 ft	38 ft	As above. Two 1/4 inch–1/2 inch fractures filled with calcite.
38 ft	41 ft 9 inches	Fresh lamproite.
41 ft 9 inches	48 ft	Contact with metamorphosed shale at 44 ft. Shale is black, hard, and fractured. All fracture planes coated with pyrite.
48 ft	58 ft	Top 0.5 ft–1 ft still metamorphosed, then get into black shale, which must be slightly metamorphosed, because it is quite hard all the way to the bottom.
58 ft	68 ft	Still some pyrite in the upper part. Less indurated towards the bottom.
68 ft	78 ft	Same as above.
78 ft	79 ft	As above.
79 ft	88 ft	First 3 ft quite indurated, metamorphosed shale getting fresher towards the bottom.
88 ft	97 ft 3 inches	From 2 ft 7 inches to 3 ft down (90 ft 7 inches–91 ft), an inclusion of lamproite material. Inclusions like this and others like it may explain why the shale is metamorphosed in places.
97 ft 3 inches	103 ft 7 inches	Shale like above, another inclusion of lamproite about 10 inches down at 98 ft or 98 ft 1 inch.

102 ft 9 inches	108 ft	5 ft 5 inches of alternating slightly metamorphosed limestone and shale. More limestone towards the top. More thoroughly mixed altered shale, limestone and possibly lamproite towards the bottom.
108 ft	117 ft	Top 6 inches (108 ft 6 inches) mixed lamproite, shale and limestone, then 9 inches (109 ft 3 inches) mostly limestone followed by 18 inches (110 ft 9 inches) of mostly brecciated limestone with minor shale and lamproite, followed by 2 ft (112 ft 9 inches) of mixed limestone, lamproite, and shale, followed by 12 ft 2 inches (114 ft 11 inches) of mostly limestone. Bottom 22 ft or so lamproite, shale, and limestone. The lamproite does not contain any phlogopite. Difficult to tell if and how much lamproitic material is included with the sediments.
117 ft	118 ft	Mixed sediment and lamproitic material.
118 ft	120 ft 6 inches	Mixed sediment and lamproitic material.
120 ft 6 inches	128 ft	Top 27 inches as above then a 1 ft 6 inch transition zone with lesser amounts of lamproitic material to limestone, dense, with a few wisps of shale.
128 ft	138 ft	Limestone full of green-gray shale partings and clots. At about 4 ft down about half limestone, half gray-green shale. Limestone clots floating in shale as well as irregular limestone lenses separated by shale.
138 ft	148 ft	Upper 4 ft 3 inches as above, becoming more limestone, possibly brecciated. Rock full of fossils, crinoids, etc. Lower 4 ft 6 inches light-gray clean limestone with vugs up to 1 inch. Rock is stylolitic.
148 ft	158 ft	Light-gray fossiliferous limestone. Vugs up to 1 inch, some lined with pyrite. Many pin-size vugs. Stylolitic. Some large fossils.
158 ft	168 ft	Limestone as above.
168 ft	178 ft	Top 20 inches clean limestone as above followed by intermixed limestone and shale down to 4 ft 5 inches. Black shale down to bottom.
178 ft	187 ft 1 inch	Shale, alternating intervals of dark-gray and reddish-brown shale.

Core hole 3–97 Elevation 1,032 ft

0 ft	2 ft 4 inches	Soil
2 ft 4 inches	10 ft	Lamproite, weathered.
10 ft	14 ft	Weathered lamproite.
14 ft	16 ft	Weathered lamproite.
16 ft	18 ft	Weathered lamproite
18 ft	20 ft	Weathered lamproite.
20 ft	22 ft	Weathered lamproite.
22 ft	24 ft	Weathered lamproite, but getting darker.
24 ft	26 ft	Relatively fresh lamproite.
26 ft	27 ft	As above.
27 ft	32 ft	Relatively fresh, dark-olive-brown-looking lamproite.
32 ft	37 ft	Top few inches still quite weathered. Then sharp contact with harder unweathered lamproite.
37 ft	42 ft	The lamproite is not a typical lamproite. No evidence of phlogopite in the rock.
42 ft	47 ft	Lamproitic material.
47 ft	52 ft	As above.
52 ft	57 ft	As above. In fracture near the top are white fracture fillings.
57 ft	67 ft	As above.
67 ft	77 ft	As above.
77 ft	78 ft	As above.
78 ft	87 ft	Contact with shale at 83 ft 10 inches. Black shale below.
87 ft	96 ft 10 inches	Black shale. Rock indurated, metamorphosed. Some high-angle fractures filled with secondary materials. Rock also breaks along high-angle fractures.

Core hole 4–97 Elevation 1,040 ft

4 ft	8 ft	Dark, metamorphosed shale (3 ft 4 inches).
8 ft	13 ft	Some black shale, then got probably into lamproite at about 9 ft.
13 ft	17 ft	Weathered lamproite.
17 ft	22 ft	Weathered lamproite. Top few feet very soft.
22 ft	27 ft	Top 2 ft 4 inches fresher, but weathered lamproite good contact with fresh, hard lamproite at 24 ft 4 inches.

Core hole 5–97 Elevation 1,045 ft

0 ft	4 ft	Soil.
4 ft	7 ft	Weathered gray shale.
7 ft	16 ft	Shale dark gray. Not indurated.
10 ft	13 ft	Shale as above. Rock is very fractured and broken-up.
13 ft	16 ft	Shale much the same as above.
16 ft	21 ft	Shale as above, but the last 3 ft or so more indurated, slightly metamorphosed.
21 ft	26 ft	Black shale, partly metamorphosed. Fractures filled with secondary minerals.
26 ft	36 ft	Slightly metamorphosed black shale. Minor high-angle fractures. Shale itself also dips.
36 ft	46 ft	Quite metamorphosed shale. Many high-angle fractures, many filled with sulfides. Last 2 inches a lamproitic material. Used a lot of water in this interval.
46 ft	56 ft	Top 6 inches lamproitic material. Sharp contact with shale black for 2 ft 11 inches sharp contact with more lamproitic material to the bottom.
56 ft	59 ft 4 inches	Lamproite fresh.
59 ft 4 inches	61 ft 2 inches	Lamproite fresh.
61 ft 2 inches	61 ft 9 inches	Lamproite.
61 ft 9 inches	64 ft 10 inches	Lamproite.
64 ft 10 inches	65 ft 10 inches	As above.
65 ft 10 inches	67 ft 4 inches	Lamproite.
67 ft 4 inches	77 ft	Top 3 ft dark-red-brown lamproite, but rock has domains of lamproite. Below this the rock has a more gray-bluish color even though the rock is not uniform. Three 1/4 inch–1/2 inch calcite veins.
77 ft	86 ft 9 inches	Lamproite, as above several calcite veins, one 0.75 inch wide.
86 ft 9 inches	96 ft 8 inches	Lamproite to 95 ft 8 inches, shale contact sharp at a 40–45° angle. Different domains, possibly indicating flow structure, apparent in the core.
96 ft 8 inches	99 ft	Black, metamorphosed shale.
99 ft	103 ft 10 inches	Black, slightly metamorphosed shale.

Core hole 6–97 Elevation 1,049 ft

0 ft	1 ft 1 inch	Soil.
1 ft 1 inch	4 ft 1 inch	Siltstone, weathered
4 ft 1 inch	7 ft 1 inch	As above
7 ft 1 inch	17 ft 1 inch	Siltstone weathered to about 12 ft 4 inches, turns into a light-medium gray, slightly altered (metamorphosed) siltstone.
17 ft 1 inch	27 ft 1 inch	Light-medium gray, slightly altered siltstone.
27 ft 1 inch	36 ft 11 inches	As above. Pyrite on a few high-angle fracture surfaces. Also oneopen irregular fracture at the top.
36 ft 11 inches	47 ft 1 inch	Siltstone as above. Still a few solution fractures and local solution features.
47 ft 1 inch	57 ft 3 inches	Same as above. Some pyrite on fractures. No solution features.
57 ft 3 inches	67 ft 5 inches	Same as above.
67 ft 5 inches	77 ft 5 inches	As above.
77 ft 5 inches	87 ft	As above, last 16 inches more dark shale.
87 ft	96 ft 10 inches	Lamproite inclusions from 18 inches to 3 ft in soft black shale. Last 4 ft 10 inches light-gray siltstone. Lost water in a bad way.
96 ft 10 inches	107 ft	Gray shale. Quite soft
107 ft	116 ft 10 inches	Gray shale.
116 ft 10 inches	127 ft	Gray shale.
127 ft	137 ft	Dark-gray-black shale.

Core hole 7–97 Elevation 988 ft

0 ft	6 ft 4 inches	Soil
6 ft 4 inches	10 ft	Weathered shale.
10 ft	18 ft	Soft weathered shale to 15 ft 6 inches. Sharp contact with limestone.
18 ft	28 ft	Limestone. At 27 ft 10 inches several thin, weathering zones (up to 1 inch). Bottom 1 ft 10 inches is mixed limestone and shale. Limestone pellets and more limestone rich areas mixed with and floating in shale.
28 ft	38 ft	Fossiliferous, mixed limestone and shale. Some intervals richer in one rock type over the other.

38 ft	48 ft	Limestone mixed with shale down to 39 ft 7 inches then a 1-inch zone with some lamproite. Back in limestone down to 41 ft 10 inches. Sharp, dipping contact with lamproite, fresh. Contains phlogopite, but very finely grained.
4 ft	58 ft	Fresh lamproite.
58 ft	67 ft 6 inches	Fresh lamproite, dark, large mica.
67 ft 6 inches	72 ft	As above.
72 ft	78 ft	Lamproite, as above.
78 ft	87 ft 10 inches	Lamproite. Still large phlogopite grains. One serpentine filled, high-angle, fracture.
87 ft 10 inches	94 ft 10 inches	Fresh lamproite.
94 ft 10 inches	98 ft	Lamproite, as above.
98 ft	107 ft 10 inches	Fresh lamproite.
107 ft 10 inches	108 ft 10 inches	Fresh lamproite.
108 ft 10 inches	109 ft 11 inches	Fresh lamproite.
109 ft 11 inches	118 ft	Top 3 ft 5 inches lamproite to 113 ft 4 inches. Limestone with thin, irregular, wavy shale partings below. Rock is metamorphosed.
118 ft	128 ft	Limestone with numerous irregular shale parting and inclusions. Rock fossiliferous.
128 ft	138 ft 1 inch	Rock much the same as above. A little more shaly limestone the last 6 inches or so.
138 ft 1 inch	148 ft 1 inch	Limestone becomes increasingly shaly, changes to shale at about 141 ft. Dark shale.
148 ft 1 inch	147 ft 11 inches	Shale recovered 9 ft 10 inches down to 157 ft 6 inches. Some slightly reddish intervals between 2 ft 6 inches and 5 ft 6 inches.
147 ft 11 inches	167 ft 11 inches	Shale. Some light-gray rounded shale balls (up to several inches, but elongated) in the shale.
167 ft 11 inches	177 ft 11 inches	Shale. Contact with limestone at 171 ft 5 inches. Limestone quite clean and dense.
177 ft 11 inches	187 ft 11 inches	Limestone as above. Stylolitic.

Core hole 8–97 Elevation 988 ft

0 ft	2 ft	Soil.
2 ft	15 ft	Soft, olive-brown weathered lamproite. Water at 13 ft.
15 ft	23 ft	Soft lamproite.
23 ft	31 ft	Lamproite becomes a bit fresher. Some small quartz pockets. Below 26 ft some contamination, possibly altered shale chips.
31 ft	38 ft	Lamproite, reddish, quite a bit of phlogopite.
38 ft	48 ft	Quite fresh lamproite, but contaminated with country rock chips.
48 ft	58 ft	Rock as above. Good mica content.
58 ft	68 ft	Contact with limestone at 66 ft. Phlogopite crystals get to be smaller towards the contact.
68 ft	78 ft	Good hard limestone. Fossiliferous in the lower part.
78 ft	88 ft	Fossiliferous limestone but quite shaly in places.
88 ft	98 ft	Fossiliferous, clean. Stylolitic limestone. Some fossils replaced by pyrite, also other pyrite concentrations.
98 ft	108 ft	Limestone more sugary, stylolitic, and fossiliferous.
108 ft	118 ft	Limestone quite clean. Slightly stylolitic and fossiliferous. Some cavities lined with calcite?
118 ft	128 ft 3 inches	Limestone down to 121 ft 4 inches. Shale below.
128 ft 3 inches	138 ft	Shale has a slight reddish sheen to it.
138 ft	143 ft 10 inches	Dark-gray shale.
143 ft 10 inches	148 ft 10 inches	Dark-gray shale.
148 ft 10 inches	158 ft 10 inches	Dark-gray shale to 155 ft 10 inches than a couple of inches of dark-gray limestone/shale, fossiliferous. Changing to cleaner fossiliferous limestone.
158 ft 10 inches	163 ft 10 inches	Good hard fossiliferous limestone.

Core hole 9–97 Elevation 1,000 ft

0 ft	4 ft 4 inches	Weathered shale.
4 ft 4 inches	6 ft 4 inches	Shale.
6 ft 4 inches	8 ft 4 inches	Shale.
8 ft 4 inches	10 ft 2 inches	Shale.
10 ft 2 inches	15 ft 2 inches	Dark-gray shale.
15 ft 2 inches	17 ft	Dark-gray shale.
17 ft	27 ft	Shale down to 22 ft 11 inches, change to limetone. Some fracturing, high-angle and calcite veining.
27 ft	30 ft	Limestone to 28 ft 2 inches. Changing to lamproite. Lamproite olive-colored but not too soft.

30 ft	35 ft 3 inches	First 8 inches still soft light-colored, then changing with a sharp contact to fresher, darker lamproite.
35 ft 3 inches	37 ft	Fresh lamproite. The lamproite shows quite a bit of color variation from bluish-brown to orange-brown.
37 ft	47 ft	Fresh lamproite.
47 ft	50 ft	Lamproite. Changing to more weathered, olive-brown lamproite at 48 ft 1 inch.
50 ft	57 ft	Weathered lamproite to 52 ft 11 inches. Abrupt change to fresh lamproite.
57 ft	67 ft	Fresh lamproite.
67 ft	77 ft	As above.
77 ft	87 ft	From approximately 77 ft 3 inches to approximately 80 ft, the lamproite is more reddish and more broken apart.
87 ft	93 ft 4 inches	Good fresh lamproite.
93 ft 4 inches	97 ft 4 inches	Good lamproite.
97 ft 4 inches	106 ft	Good lamproite.
106 ft	116 ft	About 10 inches of reddish lamproite, below limestone, altered to about 109 ft. Clean, hard limestone and shaly limestone with clean limestone clasts.
116 ft	118 ft	Shaly limestone with rounded cleaner limestone clasts or blebs.
118 ft	127 ft 6 inches	Limestone as above.
127 ft 6 inches	137 ft 6 inches	Mostly clean limestone.
137 ft 6 inches	147 ft 6 inches	Clean limestone.
147 ft 6 inches	157 ft 6 inches	Clean limestone. Last 9 inches very organic and fossiliferous.
157 ft 6 inches	167 ft 6 inches	First 6 inches organic-rich, calcareous, fossiliferous shale, followed by gray shale. Reddish shale from approximately 165 ft 6 inches to 166 ft 3 inches.
167 ft 6 inches	177 ft 6 inches	Reddish-gray shale in the first 1 ft. Some minor reddish-brown sheen in other parts of the core.
177 ft 6 inches	187 ft 6 inches	Gray shale.
187 ft 6 inches	196 ft 6 inches	Black-gray shale changing rapidly to a fossiliferous limestone at 194 ft.
196 ft 6 inches	206 ft 6 inches	Limestone.

Core hole 10–97 Elevation 997 ft

0 ft	4 ft 11 inches	Soil.
4 ft 11 inches	9 ft	Shale, gray.
9 ft	14 ft	Gray platy shale.
14 ft	18 ft	Shale as above.
18 ft	28 ft	Shale as above.
28 ft	38 ft	At approximately 32 ft shale changes to limestone which continues to 36 ft 6 inches. Then abrupt change to reddish lamproite.
38 ft	48 ft	Fresh lamproite. At about 45 ft the rock is porous looking with bladed crystals?
48 ft	58 ft	Lamproite. Some very coarse, the water probably plucks out minerals giving the rock a porous appearance. Quite a bit of mineralogical variations in this interval.
58 ft	65 ft 9 inches	Lamproite, upper 5 ft 9 inches like above, lower 2 ft more dense.
65 ft 9 inches	67 ft 8 inches	Lamproite.
67 ft 8 inches	72 ft 8 inches	Fresh lamproite.
72 ft 8 inches	77 ft 8 inches	As above.
77 ft 8 inches	85 ft	As above.
85 ft	90 ft	As above.
91 ft 9 inches	98 ft	Hard lamproite.
98 ft	108 ft	Hard lamproite.
108 ft	118 ft	Limestone contact at 114 ft 10 inches. Limestone altered.
118 ft	128 ft	Limestone.
128 ft	138 ft	Limestone.
138 ft	148 ft	Limestone.
148 ft	158 ft	Stylolized limestone. Some secondary vugs.
158 ft	168 ft	Limestone down to 163 ft 5 inches, transition zone to dark-gray shale to 164 ft 5 inches. Below that gray shale.
168 ft	178 ft	Gray shale down to 170 ft 6 inches. Below that the shale is brownish-red in places (spotty).
178 ft	188 ft	Dark-gray shale with a slight reddish-brown sheen from 179 ft 5 inches to 181 ft 5 inches. Some lighter-gray shale clasts in the last 5 inches.
188 ft	198 ft	Shale.
198 ft	208 ft	Shale to 198 ft 1 inch, then limestone to 208 ft 3 inches.

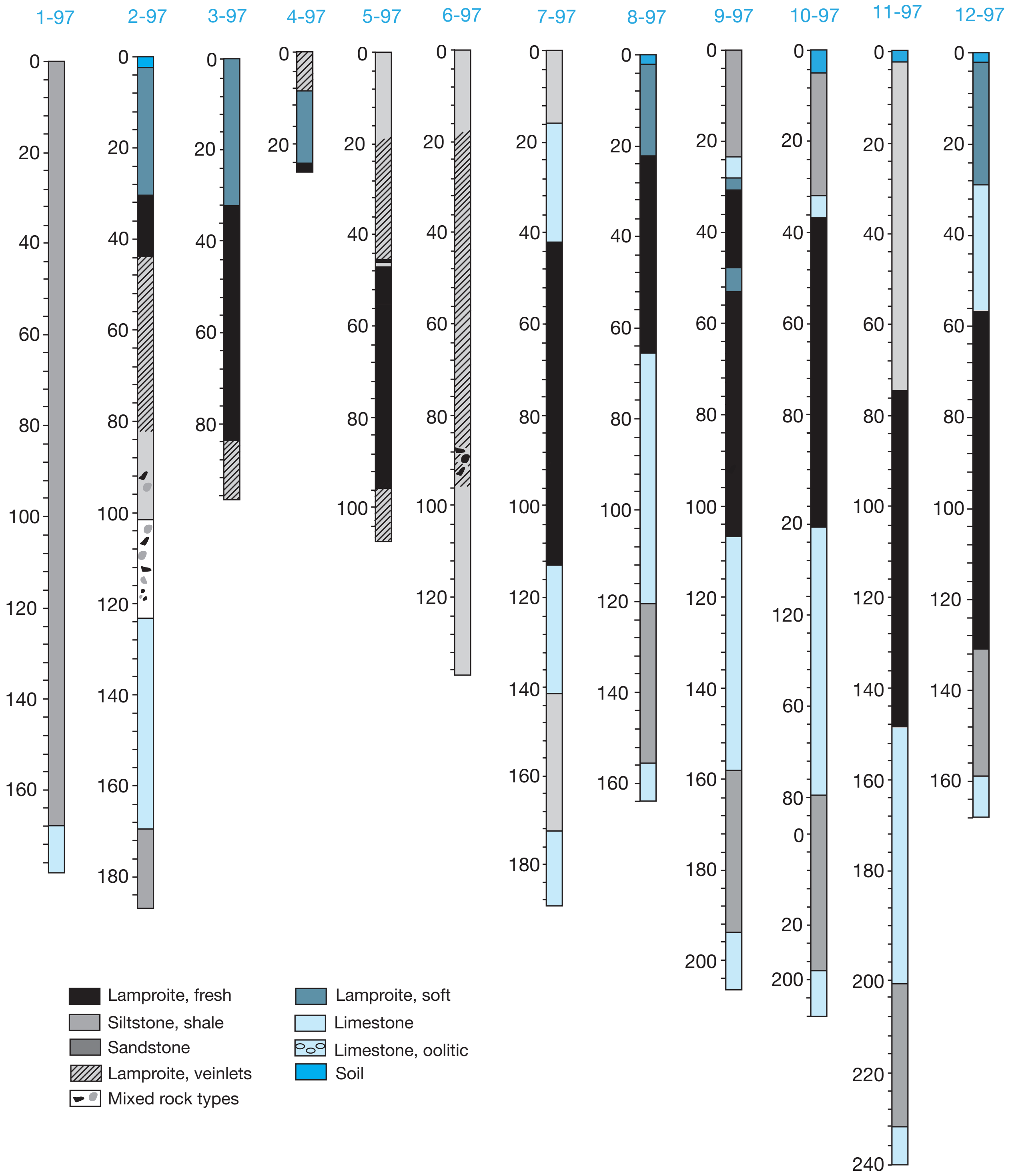
Core hole 11–97 Elevation 1,018 ft

0 ft	2 ft	Soil.
2 ft	9 ft 6 inches	Brown, altered shale.
9 ft 6 inches	14 ft	Shale turning from weathered brown gray at the top to a medium gray near the bottom.
14 ft	18 ft	Gray shale, still slightly weathered.
18 ft	28 ft	Gray shale.
28 ft	37 ft	Gray shale.
37 ft	43 ft	Gray shale. In the last 1 ft several horizontal calcite veinlets up to 0.25 inch–0.5 inch thick.
43 ft	48 ft	Shale. Calcite veinlets throughout the interval.
48 ft	58 ft	Shale.Turns quite dark in this interval. Still some calcite (thin) veinlets.
58 ft	68 ft	The last 4 ft are harder, a little coarser grained, possibly slightly altered.
68 ft	78 ft	First altered, hard, broken-up shale with some calcite fracture filling. Contact with lamproite at 74 ft 8 inches.
78 ft	78 ft 11 inches	Lamproite (lost circulation because of clay build-up around core catcher). Small mica flakes, lamproite reddish-brown.
78 ft 11 inches	88 ft 8 inches	Lamproite, still not dark and fresh.
88 ft 8 inches	97 ft 9 inches	Lamproite quite fresh.
97 ft 9 inches	100 ft 9 inches	Lamproite as above.
100 ft 9 inches	106 ft 3 inches	Good fresh lamproite.
108 ft 7 inches	115 ft 4 inches	Fresh lamproite.
115 ft 4 inches	117 ft 9 inches	Fresh lamproite.
117 ft 9 inches	122 ft 9 inches	Good fresh lamproite.
122 ft 9 inches	128 ft 6 inches	Fresh lamproite.
128 ft 6 inches	137 ft 7 inches	Fresh lamproite. One high-angle fracture.
137 ft 7 inches	138 ft 7 inches	Fresh lamproite.
138 ft 7 inches	148 ft 8 inches	Fresh lamproite, last 6 ft 8 inches are starting to get altered to a reddish-brown color.
148 ft 8 inches	158 ft 8 inches	Hair-sharp contact with altered limestone at the top followed by 1 ft 5 inches (160 ft 1 inch) of baked limestone (does not fizz), followed by 2 ft 10 inches (162 ft 11 inches) limestone, fossiliferous. Then about 2 ft 9 inches of mixed limestone and lamproitic fluid, rock fizzes (165 ft 8 inches), last interval is limestone.
158 ft 8 inches	168 ft 8 inches	Limestone. Lower 2.5 inches becomes shaly limestone with cleaner limestone balls or blebs in a darker shaly limestone matrix.
168 ft 8 inches	178 ft 10 inches	First 2 ft as above, below 2 inches of dark, organic limestone followed by clean, stylolized limestone.
178 ft 10 inches	188 ft 11 inches	Clean, stylolized limestone.
188 ft 11 inches	198 ft 11 inches	Clean, stylolized limestone.
198 ft 11 inches	209 ft 1 inches	First 2 ft (200 ft 11 inches) clean limestone, then 4 inches of shale, followed by 1 ft 4 inches of limestone alternating with shale followed by dark-gray shale.
209 ft 1 inches	219 ft 1 inches	Shale. From 211 ft 1 inch down to 218 ft 5 inches, here and there dark-brown streaks and patches.
219 ft 1 inch	228 ft 10 inches	Dark-gray shale. Some limy thin streaks in the middle of the interval. Also some lighter-brown-gray blebs towards the bottom.
228 ft 10 inches	230 ft 4 inches	Shale as above.
230 ft 4 inches	239 ft 9 inches	Contact with limestone at 232 ft, last 4 inches is a shale/limestone hash.

Core hole 12–97 Elevation 995 ft

0 ft	2 ft	Soil.
2 ft	8 ft 6 inches	Weathered olive-brown shale.
8 ft 6 inches	13 ft 3 inches	As above.
13 ft 3 inches	19 ft 4 inches	As above.
19 ft 4 inches	25 ft 5 inches	As above.
23 ft	28 ft	Shale.
28 ft	33 ft	Shale to 29 ft, below limestone dense, some secondary porosity near the bottom.
33 ft	38 ft	Limestone. At about 33 ft 4 inches, we get an interval with oolites.
38 ft	48 ft	Clean, fossiliferous limestone.
48 ft	58 ft	Limestone, fossiliferous. Light-gray with some darker-gray intervals.
57 ft 4 inches	68 ft	At 59 ft 3 inches lamproite. Top 4 inches is altered, olive-brown, followed by quite fresh material.
68 ft	78ft 1 inches	Reddish-gray to black lamproite. Soft in some places.
78 ft 1 inches	88 ft 1 inches	Lamproite as above.

88 ft 1 inch	98 ft 1 inch	Lamproite, as above. Soft in some areas. Color reddish-gray-brown to black.
98 ft 1 inch	105 ft 10 inches	Lamproite a little darker and harder than in the above interval.
105 ft 10 inches	108 ft 5 inches	Hard, fresh lamproite.
108 ft 5 inches	117 ft 11 inches	Hard, fresh lamproite.
117 ft 11 inches	121 ft 5 inches	Top of the core all broken up. Fresh lamproite.
121 ft 5 inches	122 ft 10 inches	Fresh lamproite.



APPENDIX FIGURE 4.1—Graphic representation of drill core from holes 1-97 to 12-97.

Appendix 5—Brief description of core from drill holes 1–98 through 6–98 together with graphic logs of the lithologies encountered.

Core hole 1–98 Elevation 982 ft

0 ft	12 ft 4 inches	Casing to 10 ft 4 inches, below it a brown, soft sandy type of material having a fair amount of very small mica flakes in it. Probably silty shale.
12 ft 6 inches	14 ft 4 inches	Limestone intermixed with what looks like the sandy material up above. Looks like oolites or quartz grains also.
14 ft 4 inches	18 ft 4 inches	Limestone having progressively less of the brown specks in it. Lower few feet good limestone. Towards the bottom limestone is more silty and shows signs of physical disturbance (storm events?). May also have lost some at about 14 ft 10 inches where there is a break in the rock and it is very brown and altered.
18 ft 4 inches	21 ft	As above.
21 ft	25 ft 2 inches	Limestone, but it is very rusty especially along fractures.
25 ft 2 inches	28 ft	Limestone as above with intermixed shale. Rock has a blotchy appearance.
34 ft 10 inches	38 ft	Heavily fractured and iron-stained limestone.
28 ft	34’10 inches	Intermixed shale and limestone. Some layers (approximately 3–4 inches) more shale-rich, others more limestone-rich.
38 ft	48 ft	Limestone very porous, fractured and iron-stained. Breaks easily.
56 ft	59 ft	Limestone as above.
59 ft	69 ft	Limestone as above. Some silt or shale in the last 2 ft.
69 ft	70 ft 5 inches	Limestone.
70 ft 5 inches	71 ft	Dark-gray shale.
71 ft	71 ft 2 inches	Lamproitic material.
69 ft	73 ft 9 inches	Dark-gray shale, except for the lower 2 inches that appear to be metamorphosed. Big fracture, open, with 1/4-inch size crystals.
73 ft 9 inches	75 ft	Mixed lamproitic material plus limestone and shale.
75 ft	75 ft 3 inches	Lamproite, soft, shows phlogopite—may have lost some.
75 ft 3 inches	79 ft	Mixed hard limestone and shale and lamproite material. Rock metamorphosed.
79 ft	89 ft	The rock is probably a metamorphosed shale or similar rock with lamproite liquid mixed with it.
89 ft	99 ft	Lamproitic material—lots of fractures and calcite? Veining in this interval as well as above.
99 ft	109 ft	As above.
109 ft	109 ft 6 inches	Lamproitic material.
109 ft 6 inches	112 ft	Altered shale.
112 ft	114 ft 4 inches	Lamproitic material.
114 ft 4 inches	119 ft	Altered shale. The shale has quite a few calcite-filled thin fractures, many mm in size.
119 ft	128 ft 10 inches	Blocky shale. Probably still a bit affected by the heat of the intrusion.
128 ft 10 inches	139 ft	Black shale.
139 ft	144 ft	Black shale.
144 ft	149 ft	Lamproitic material.
149 ft	149 ft 7 inches	Lamproite.
149 ft 7.5 inches	150 ft 6 inches	Sharp change to black shale and then gradual change to limestone.
150 ft 6 inches	159 ft 2 inches	Limestone.
159 ft 2 inches	169 ft 3 inches	Limestone fossiliferous, stylolized, and patches of coarser recrystallized material.
169 ft 3 inches	179 ft 3 inches	Limestone as above.
179 ft 3 inches	189 ft 4 inches	Limestone as above.
189 ft 4 inches	199 ft 4 inches	Limestone as above.
199 ft 4 inches	209 ft 5 inches	Limestone as above.
209 ft 5 inches	219 ft 6 inches	Limestone as above, but the last 6 ft is darker than the limestone above as a result of more silty limestone intervals.
219 ft 6 inches	224 ft 2 inches	Limestone as above, then quite rapid change to shale.
224 ft 2 inches	229 ft 4 inches	Gray shale.
229 ft 4 inches	239 ft	Dark shale, actually may be siltstone.
239 ft	243 ft 6 inches	Dark shale as above.
243 ft 6 inches	249 ft 10 inches	All shale or silty shale, except for a 1-inch limy bed at 248 ft.
249 ft 10 inches	259 ft 6 inches	Gray silty shale.
259 ft 6 inches	260 ft 7 inches	Gray silty shale.
260 ft 7 inches	269 ft 8 inches	Gray silty shale.
269 ft 8 inches	279 ft 8 inches	As above.

279 ft 8 inches	284 ft	Silty shale as above.
284 ft	286 ft 11 inches	Sharp contact with very fossiliferous limestone.
286 ft 11 inches	287 ft 4 inches	Dark-gray shale.
287 ft 4 inches	294 ft 9 inches	Dark-gray shale as above.
294 ft 9 inches	295 ft 8 inches	Fairly quick change to fossiliferous shaly limestone.

Core hole 2–98 Elevation 985 ft

0 ft	7 ft	Soil.
7 ft	17 ft	Limestone. A bit iron-stained in places due to the weathering.
17 ft	18 ft 1 inches	Limestone as above.
181 ft 1 inch	23 ft 8 inches	Limestone as above.
23 ft 8 inches	28 ft	Limestone. Quite a bit of silty or shaly material in places.
28 ft	31 ft 8 inches	Limestone as above.
31 ft 8 inches	32 ft	Weathered lamproite.
32 ft	38 ft	Lamproite. The rock has good visible phlogopite in it.
38 ft	48 ft	Lamproite.
48 ft	58 ft	Lamproite.
58 ft	67 ft 8 inches	Lamproite, some of it quite gritty and soft.
67 ft 8 inches	75 ft 8 inches	Good dark lamproite.
75 ft 8 inches	82 ft 6 inches	Nice dark lamproite.
82 ft 6 inches	84 ft 4 inches	Good lamproite.
84 ft 4 inches	85 ft 4 inches	Good lamproite.
85 ft 4 inches	88 ft	Good lamproite.
88 ft	89 ft 1 inches	Lamproite.
89 ft 1 inch	93 ft 10 inches	Lamproite.
93 ft 10 inches	97 ft 10 inches	Lamproite.
97 ft 10 inches	101 ft 10 inches	Lamproite.
101 ft 10 inches	107 ft 11 inches	Limestone. Sharp contact—limestone shows visible alteration for about 2 ft. Limestone stylolitic.
107 ft 11 inches	117 ft 10 inches	Limestone, stylolytic with some intermixed shale as patches or thin wisps.
117 ft 10 inches	128 ft	Limestone, stylolitic, lots of dark shaly wisps. Last 2 ft is cleaner dense limestone, with some darker (2 inches) intervals.
128 ft	128 ft 9 inches	Limestone quite clean and dense.
128 ft 9 inches	129 ft 7 inches	Transition to dark shale below.
129 ft 7 inches	132 ft 6 inches	Dark shale. Some thin limestone stringers throughout.
132 ft 6 inches	138 ft	Dark silty shale, probably calcareous, with some thin stringers of limy material.
138 ft	147 ft 6 inches	Shale as above.
147 ft 6 inches	157 ft 7 inches	Shale as above.
157 ft 7 inches	162 ft 9 inches	Shale as above.
162 ft 9 inches	167 ft 7 inches	Limestone very fossiliferous—first few inches, then a dense limestone having a few stylolites and pores.
167 ft 7 inches	177 ft 8 inches	Dense, stylolitic limestone, minor thin intervals of shaly material.

Core hole 3–98 Elevation 990 ft

0 ft	3 ft 3 inches	Soil.
3 ft 3 inches	6 ft 6 inches	Limestone.
6 ft 6 inches	13 ft 3 inches	Soft, olive-brown, weathered lamproite. Has a 1 ft 3 inches limy bed in the interval.
13 ft 3 inches	15 ft 3 inches	Weathered lamproite, soft, golden brown.
15 ft 3 inches	17ft 3 inches	As above.
17 ft 3 inches	19 ft	Soft lamproite.
19 ft	21 ft 6 inches	Soft lamproite.
24 ft 6 inches	26 ft	Soft, weathered lamproite.
26 ft	26 ft 5 inches	Soft lamproite, may have lost some.
26 ft 5 inches	28 ft 5 inches	Hard lamproite.
28 ft 5 inches	29 ft	Probably soft lamproite.
29 ft	34 ft	Hard lamproite. Quite a bit of color variation in the core.
34 ft	38 ft 5 inches	Hard lamproite, quite a bluish sheen to the rock. Lots of good mica towards the bottom.

38 ft 5 inches	47 ft 7 inches	Lamproite, quite broken up.
47 ft 7 inches	56 ft 10 inches	Lamproite.
56 ft 10 inches	58ft	Hard lamproite.
58 ft	63 ft 3 inches	Hard lamproite.
63 ft 6 inches	67 ft 11 inches	Hard lamproite.
67 ft 11 inches	77 ft 11 inches	Hard lamproite.
7 ft 11 inches	81 ft 3 inches	Lamproite.
81 ft 3 inches	84 ft 2 inches	Limestone, altered.
84 ft 2 inches	85 ft 2 inches	Lamproite.
85 ft 2 inches	87 ft 11 inches	Limestone.
87 ft 11 inches	98 ft	Limestone.
98 ft	108 ft	Limestone. Some stylolites and minor shale wisps, one thin (1.5-inch) dark-shale interval at 99 ft 4 inches.
108 ft	117 ft 11 inches	Limestone, stylolytic, dense.
117 ft 11 inches	128 ft 1 inch	Limestone as above.
128 ft 1 inch	129 ft 10 inches	Limestone as above.
129 ft 10 inches	138 ft	Shale gray. Fairly sharp transition.

Core hole 4–98 Elevation 988 ft

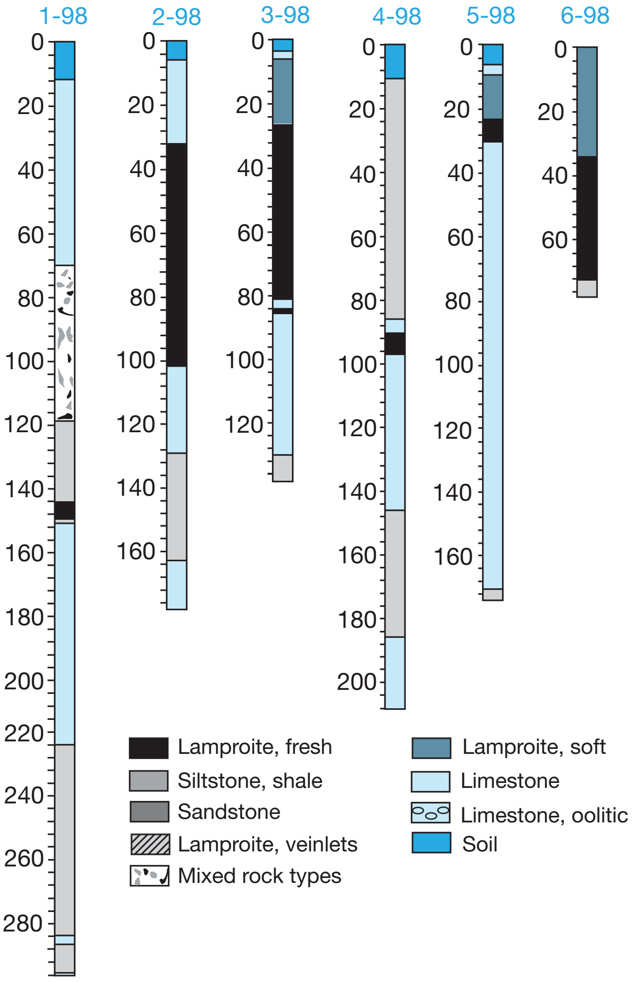
0 ft	11 ft 4 inches	Soil.
11 ft 4 inches	18 ft	Gray shale, weathered to olive brown.
18 ft	22 ft 6 inches	Weathered olive-brown shale.
22 ft 6 inches	28 ft	Turning to gray shale.
28 ft	38 ft	Gray shale.
38 ft	48 ft	Gray shale.
48 ft	54 ft 3 inches	Gray shale.
54 ft 3 inches	62 ft 8 inches	Gray shale.
62 ft 8 inches	67 ft 9 inches	Gray shale.
67 ft 9 inches	77 ft 11 inches	Gray shale.
77 ft 11 inches	85 ft 10 inches	Gray shale.
85 ft 10 inches	88 ft	Rapid change to limestone, dense.
88 ft	90 ft 4 inches	Limestone as above.
90 ft 4 inches	96 ft 10 inches	Sharp contact with lamproite. Does not contain good visible phlogopite. Lots of very small phlogopite.
96 ft 10 inches	97 ft 11 inches	Back in limestone, sharp contact.
97 ft 11 inches	100 ft 2 inches	Altered limestone.
100 ft 2 inches	101 ft 8 inches	Clean, dense limestone.
101 ft 8 inches	107 ft 11 inches	Intermixed limestone and shaly intervals. Most of the shale occurs as wavy-wisps and stringers.
107 ft 11 inches	114 ft 11 inches	Limestone as above, with quite a bit of shale.
114 ft 11 inches	117 ft 4 inches	Mixed, very fossiliferous shale and limestone.
117 ft 4 inches	118 ft	Broken-up, rounded limestone clasts surrounded by shale.
118 ft	118 ft 8 inches	As above.
118 ft 8 inches	128 ft	Clean, stylolitic limestone.
128 ft	138 ft 2 inches	Clean, stylolitic limestone.
138 ft 2 inches	145 ft 10 inches	Limestone as above.
145 ft 10 inches	146 ft 10 inches	Transition zone to shale.
146 ft 10 inches	148 ft 3 inches	Shale.
148 ft 3 inches	155 ft 7 inches	Gray shale.
155 ft 7 inches	156’7 inches	Reddish shale.
156 ft 7 inches	157’7 inches	Gray shale.
157 ft 7 inches	158 ft	Gray shale.
158 ft	168 ft 3 inches	Mostly gray shale. Here and there a dark-brownish-gray tint to the shale in the upper 2 ft.
168 ft 3 inches	178 ft 3 inches	Gray shale containing a few, light-brownish-gray, silty intervals (from 1 inch to 2 inches).
178 ft 3 inches	185 ft 8 inches	Gray shale.
185 ft 8 inches	188 ft 3 inches	Limestone with wispy shale stringers.
188 ft 3 inches	198 ft 4 inches	Limestone.
198 ft 4 inches	207 ft 11 inches	Limestone as above, some stylolites.

Core hole 5–98 Elevation 968 ft

0 ft	6 ft	Soil.
6 ft	8 ft 6 inches	Limestone, altered.
8 ft 6 inches	9 ft 9 inches	Lamproite, hard, bluish color.
9 ft 9 inches	14 ft	Soft lamproite.
14 ft	18 ft	Probably soft lamproite.
22 ft	23 ft 3 inches	Soft lamproite.
23 ft 3 inches	28 ft	Fresh lamproite.
28 ft	30 ft 7 inches	Lamproite, not too fresh and hard.
30 ft 7 inches	37 ft 10 inches	Limestone, first 2 ft 7 inches quite metamorphosed.
37 ft 10 inches	47 ft 10 inches	Limestone.
47 ft 10 inches	58 ft	Mixed shale and limestone, mostly very fossiliferous.
58 ft	59 ft 4 inches	Fossiliferous shaly limestone.
59 ft 4 inches	68 ft	Very clean, fossiliferous, limestone, a few stylolites.
68 ft	78 ft 1 inch	Limestone, first 5 ft 4 inches as above, then wisps and thin laminae of shale common, lots of bryozoans throughout.
78 ft 1 inch	88 ft 2 inches	Limestone. Quite clean, except for minor shale wisps. Lower 2 ft 6 inches has irregular chunks of darker limestone in the clean, creamy-colored limestone. Lots of bryozoans throughout.
88 ft 2 inches	98 ft 2 inches	Limestone. First approximately 7 ft as above, then limestone becomes again quite clean, but still has some of the above character.
98 ft 2 inches	108 ft 2 inches	Limestone as above, about 2 ft above bottom the rock loses its punky character and becomes a dense fine-grained limestone containing shaly wisps and intervals.
108 ft 2 inches	118 ft 2 inches	Upper approximately 3 ft quite shaly, then becomes a clean stylolitic limestone.
118 ft 2 inches	128v2 inches	Limestone as above.
128 ft 2 inches	138 ft 3 inches	Limestone containing shaly bands and wisps throughout.
138 ft 3 inches	148 ft 3 inches	Limestone as above.
148 ft 3 inches	158 ft 3 inches	Limestone, quite a few shaly irregular wisps and bands throughout.
158 ft 3 inches	168 ft 3 inches	Limestone with shale, becoming more or less all calcareous shale towards the bottom, last 7 ft again cleaner limestone.
168 ft 3 inches	170 ft 3 inches	Limestone mixed with shale.
170 ft 3 inches	173 ft 3 inches	Shale gray, very fossiliferous near top.

Core hole 6–98 Elevation 1005 ft

0 ft	3 ft	Soil.
3 ft	5 ft	Soft lamproite.
5 ft	7 ft	Soft lamproite.
7 ft	9 ft	Soft lamproite.
9 ft	11 ft	As above, but getting a bit harder.
11 ft	14 ft	Soft lamproite.
14 ft	18 ft	Soft lamproite.
18 ft	21 ft	Soft lamproite.
21 ft	23 ft	Soft lamproite.
23 ft	25 ft	Soft lamproite.
25 ft	28 ft	Slightly harder and fresher lamproite.
28 ft	33 ft	Harder lamproite.
33 ft	38 ft	Relatively fresh, hard lamproite. Nice and hard at the bottom.
38 ft	47ft 8 inches	Fresh lamproite.
47 ft 8 inches	52 ft 5 inches	Fresh lamproite.
52 ft 5 inches	58 ft	Lamproite. Nice botryoidal calcite growth in cavities.
58 ft	68 ft	Lamproite, quite a few fractures filled with calcite.
68 ft	72 ft 5 inches	Lamproite, sharp contact with shale below. Some shale chunks caught in the lamproite. Quite a few calcite veinlets.



APPENDIX FIGURE 5.1—Graphic representation of drill core from holes 1-98 to 6-98.

Appendix 6—Brief description by Wagner of core from 21 shallow drill holes at Silver City Dome.

SILVER CITY META AREA CORES

Core hole #1

7 ft 5 inches		Quartzite, moderate-grayish-green (5G 4/2), very fine sand grains cemented with silica. Mica sparingly present on bedding planes. Locally speckled with 1/8-inch bleb-like areas of darker-green color (about 60% recovery).
7 ft 5 inches	13 ft	Shale, yellowish-gray (5Y 7/2), fissile, slightly silty, apparently entirely unaltered. (50%) Grades downward into
13 ft	13 ft 2 inches	Siltstone, very light gray (H8), very finely micaceous; no apparent alteration. (100%) Grades downward into
13 ft 2 inches	13 ft 5 inches	Shale, light-olive-gray (5Y 6/1), very slightly silty, slightly micaceous, a few wood fragments along bedding. Grades downward through a siltstone (about 3/4 inch thick) into (100%)
13 ft 5 inches	22 ft	Sandstone, very pale orange (10YR 8/2) to grayish-orange (10YR 7/4), very fine grained, well-sorted, slightly micaceous, many very small blebs of iron oxide throughout. Generally fairly well-bedded and thin-bedded (1/16 inch to 1/4 inch). Basal 8 inches is crossbedded and contains very many small fragments of carbonaceous matter on the bedding planes. (100%)
22 ft	28 ft 5 inches	Sandstone, very light gray (N8), very fine grained, thin-bedded, the beds being about 3/4 inch thick, separated by 1/16-inch beds of carbonaceous matter that contains a few mica plates. Locally the carbonaceous beds are lenticles that feather out laterally. Small-scale intraformational folding is present at the top. (100%)
28 ft 5 inches	51 ft 8 inches	Sandstone, very light gray (N8), very fine grained, massive, relatively porous, slightly micaceous. Strongly crossbedded locally and when crossbedded, the bedding is brought out by the thin carbonaceous layers. Lower 8 inches is gradational to the underlying (Ireland sandstone to here)
51 ft 8 inches	84 ft	Siltstone, medium-light-gray (N6), carbonaceous, very finely micaceous. Brownish lenticular units throughout at intervals of a foot or slightly less. (Robbins shale)

Core hole #2 (250 ft southwest of shaft)

10 ft		Quartzite, light-bluish-gray (5B 7/1), very slightly micaceous, much chlorite (?)
10 ft	15 ft	Sandstone, light-olive-gray (5Y 6/1), slightly micaceous, crossbedded toward base. (Ireland sandstone)
15 ft	63 ft	Claystone, medium-light-gray (N6), contains a little carbonaceous matter and very fine mica. Slightly silty. Many moderate-yellowish-brown (19YR 5/4) lenses. Ironstone concretions (?) throughout. Actually is fairly well bedded and breaks along bedding planes. (Robbins shale)

Core hole #3 (350 ft southeast of shaft)

11 ft		Quartzite, pale-yellowish-brown (10YR 6/2) to moderate-yellowish-brown (10YR 5/4), locally only poorly silicified. Many greenish blebs (chlorite?) locally. (Ireland)
11 ft	15 ft	Shale, silty, yellowish-gray (5% 7/2) to light-olive-gray (5Y 5/2). No alteration apparent micaceous.
15 ft	40 ft	Shale, medium-gray (N5), very slightly silty, a little chlorite along joint planes in upper part. Lower part contains many reddish ironstone concretions. (Robbins shale)

Core hole #4

7 ft 6 inches		Sandstone, grayish-orange (10YR 7/4), very micaceous, very fine grained, well-sorted, well-bedded but locally crossbedded, many dark bleb-like areas in lower part. (T.D. Ireland)

Core hole #5 (300 ft west of shaft)

18 ft		Quartzite, very light gray (N8) with distinct greenish cast or bluish cast locally. About 1 ft above the

		base is a greenish body that appears to be almost entirely olivine (?) near which are vugs filled with small tetrahedral crystals, tentatively identified as
18 ft	25 ft	Shale, light-olive-gray (5Y 6/1) in the upper foot and medium-light-gray (N6) below that. One ironstone concretion (?) noted. (Robbins)

Core hole #6 (600 ft west of shaft)

19 ft		Quartzite, yellowish-gray (5Y 8/1) to grayish-orange-pink (5YR 7/2). Locally pale-green (5G 7/2). Generally very fine grained, well-sorted sandstone cemented with silica. Cementation less complete at base. Slightly to moderately micaceous silty lenses common near base. (Ireland)
19 ft	23 ft	Siltstone, light-gray (N7) much finely divided carbonaceous matter. Slightly micaceous. (Robbins)

Core hole #7

12 ft 5 inches		Sandstone, grayish-orange (10YR 7/4) to very pale orange (10YR 8/2), very fine grained, well-sorted, locally crossbedded, slightly to moderately micaceous. (Ireland)
12 ft 5 inches	17 ft	Shale, very pale orange (10YR 8/2) at top of light-olive-gray (5Y 6/1) at base. Very finely micaceous and silty. Carbonaceous.
17 ft	21 ft	Sandstone, grayish-orange (10YR 7/4), very fine grained, finely micaceous. Locally crossbedded.

Core hole #8 (200 ft south of #7)

11 ft		Quartzite, very light gray (N8) with a distinct greenish cast. Very fine grained, cemented with silica. Bedding thin and regular, but locally crossbedded. Slightly micaceous.
11 ft	15 ft	Sandstone, very fine grained, light-grayish-orange (10YR 8/4), locally crossbedded and irregularly bedded, but generally thin, well-bedded carbonaceous fragments and mica flakes present but not common.
15 ft	16 ft	Siltstone, light-olive-gray (5Y 6/1), finely micaceous, sandy at base.
16 ft	18 ft 5 inches	Sandstone, yellowish-gray (5Y 8/1) to light-olive-gray (5Y 6/1), harder than that directly above the slot and probably has some added silica, poorly bedded, very fine grained, well-sorted, some mica.
18 ft 5 inches	21 ft	Shale, medium-light-gray (N6), very slightly silty, ironstone concretions (?) present.

Core hole #9 (300 ft east of shaft)

30 ft 9 inches		Quartzite, yellowish-gray (5Y 8/1) with distinct pinkish cast locally, to very light gray (N8) with greenish cast. Very fine grained moderately micaceous and many small carbonaceous fragments locally. Locally crossbedded and swirly-bedded. Silicification generally complete but is locally incomplete where bedding is most evident. This bedding is due to thin siltstone bands which were apparently not as readily permeated by the silicifying solution.
30 ft 9 inches	35 ft	Shale, medium-light-gray (N6), very slightly silty. Some ironstone concretions.

Core hole #10 (800 ft east of shaft)

22 ft		Quartzite, light-gray (N7) with greenish cast in upper 14 ft and yellowish-gray (5Y 8/1) in lower 8 ft. Upper part completely silicified. Lower part only partially silicified. Well-bedded, locally crossbedded. Very fine grained, well-sorted, slightly micaceous.
22 ft	26 ft	Shale, medium-light-gray (N6), unaltered. Some ironstone at top.

Core hole #11

2 ft		SiO_2 dark-gray (N3), seamed with white veinlets of quartz. The uppermost 5 inches contains many small, roundish to irregularly shaped white quartz which may represent fossils. At the outcrop I have found meta Haskell limestone that looked just like this and did not react to acid either. (90% recovery Haskell Limestone)

2 ft	3 ft 8 inches	SiO_2, dark-gray (N3) with some greenish areas. This I believe represents the upper, calcareous (fossiliferous) part of the Vinland shale. (Vinland shale)
3 ft 8 inches	9 ft	Shale, medium-light-gray (N6), slightly micaceous altered to quartzite practically throughout, excepting basal 3 inches, which is soft and unaltered. (Vinland shale)
9 ft	12 ft	SiO_2, between very pale blue (5B 8/2) and light-blue (53 7/6). Has many darker-blue or greenish areas, oval-shaped to circular, that looks as though they might originally have been Osagia algae or fusulinids. I think this is the altered Westphalia. (Westphalia Limestone)
12 ft	15 ft	Quartzite, light-brownish-gray (5YR 6/1), very thin bedded, the interlaminations being white. Softer greenish material occurs locally at 13 ft 4 inches. (Tonganoxie sandstone)
15 ft	26 ft	Mica rock grayish-yellow (5Y 8/4) to yellowish-gray (5Y 7/2). Cuttings only. No core.

Core hole #12

6 inches		Shale, grayish-orange (10YR 7/4), punky. No silicification.
6 inches	27 ft 9 inches	Sandstone, grayish-orange (10YR 7/4) slightly silicified, very fine grained, well-sorted, well-bedded but locally crossbedded. Silty with carbonaceous fragments toward base.
27 ft 9 inches	28 ft	Shale, light-gray (N7), very slightly silty.

Core hole #13

20 ft		Quartzite, very light gray (N8) to light-gray (N7), locally with distinct greenish cast. Many small dark blebs throughout, well-bedded, locally crossbedded. Silicified completely throughout.
20 ft	22 ft	Shale, medium-light-gray (N6), slightly silty, micaceous.

Core hole #14

		George Hills' record shows this hole as all mica rock. No core or depth given. George told me later that they got about 3 ft of quartzite at the top and then all mica rock.

Core hole #15

7 ft 3 inches		Quartzite, very light gray (N8). Has distinct greenish and bluish casts locally. The colors are due to addition of greenish to bluish quartz in the interstices and as partial replacement of limonitic blebs (?). Generally massive and unbedded except near the center. Very micaceous. (Tonganoxie)
7 ft 3 inches	8 ft 8 inches	Quartzite, dark-gray (N3) to very light gray (N8) consisting of alternating beds (about 4 inches) of silicified sandstone and shale, the shale being the dark-gray. The shale is only partly silicified near the base. Micaceous.
8 ft 8 inches	12 ft 3 inches	Quartzite, very light gray (N8) with many very thin lenticular partings of black siltstone. Micaceous. Very fine grained.
12 ft 3 inches	18 ft	Siltstone and sandstone, alternating in 1/8-inch (sandstone) and 1/16-inch (siltstone) beds. The siltstone is nearly black and very micaceous and occurs as very thin lenticles interlaminated in the sandstone. Relatively unaltered.
18 ft	21 ft	Siltstone, medium-dark-gray (N4), very micaceous. A few beds of very fine grained, very light gray (N8) sandstone included. Soft, relatively unaltered.

Core hole #16

		Igneous rock, highly altered, approximately light-olive-gray (5Y 6/1) with yellowish spots in it. Very micaceous. One part of the sample had a quartzite (looked like a fragment of a core) embedded in the igneous material. Practically no core. No depth given.

Core hole #17

4 ft		Quartzite, very light gray (N8), very micaceous. Very fine grained. Some pistachio-green alteration. (Tonganoxie)

4 ft	4 ft 8 inches	Siltstone, light-olive-gray (5Y 6/1) very micaceous. Soft unaltered. Grade downward into
4 ft 8 inches	13 ft	Shale, silty, medium-gray (N5), well-bedded, micaceous. (Weston)

Core hole #18

41 ft 6 inches		No core—George Hill's record shows this as mica rock.
41 ft 6 inches	66 ft	Igneous rock—General color is moderate-olive-brown (5Y 4/4) to olive-gray (5Y 3/2). Relatively coarse grained, large amber-colored mica books, black nearly equidimensional iron magnesium; light-green or pistachio-green mineral as blobs (olivine?). A few calcite (it fizzed) veinlets cut the cores.
66 ft	72 ft	Shale, dark-gray (N3), fissile, no mica or silt or ironstone. (Robbins or Weston shale)

Core hole #19

3 ft		Quartzite, greenish-gray (5G 6/1), absolutely solid SiO_2, very thin bedded. Very poor recovery. A few fragments are dark-pinkish-gray (5YR 7/1) with many iron blebs. (Robbins shale)
3 ft	5 ft	Quartzite, medium-dark-gray (N4), brecciated. I think this is Haskell. Poor recovery. (Haskell)
5 ft	16 ft	Quartzite, dark-gray (N3) unbedded to well-bedded. (Vinland)
16 ft	21 ft	Limestone, generally light gray (N7), considerably altered locally but Osagia algae and calcareous nature still quite obvious. (Westphalia)
16 ft	25 ft	Siltstone, medium-gray (N5) very micaceous and thin-bedded. Interlaminae are light-colored very fine grained sandstone. This is silicified in local areas.
25 ft	41 ft	Sandstone, light-gray (N7) and siltstone, light-olive-gray (5Y 6/1) interlaminated in very thin laminae. Sandstone most prevalent in upper 4 ft. Very micaceous. Seamed with a few calcite veinlets. Only locally silicified and then only slightly.

Core hole #20

8 ft 5 inches		Quartzite, very light gray (N8) locally with a distinct greenish cast. Very micaceous, much added greenish (chloritic?) silica.
8 ft 5 inches	10 ft	Clay, yellowish-gray (5Y 8/1), may be alteration product of something but seems to fill this interval. Very poor recovery.
10 ft	31 ft	Sandstone, very light gray (N8) and siltstone, light-olive-gray (5Y 6/1), both very micaceous, interlaminated, the sandstone generally predominating. Sandstone locally silicified.
31 ft	34 ft 8 inches	Siltstone, light-olive-gray (5Y 6/1) with a few as interbeds. Very micaceous.
34 ft 8 inches	41 ft	Shale, medium-light-gray (N6), very slightly silty, fissile, locally micaceous and silty or very fine sandy. (Weston)

Core hole #21

1 ft	21 ft	Decomposed granite or yellow mica (4 ft of core)
21 ft	65 ft	Decomposed granite or dark-colored mica (38 ft of core)
65 ft	83 ft	Quartzite (13 ft of core)
83 ft	90 ft	Slate with layers of quartzite (3 1/2 ft of core)
90 ft	94 ft	Slate with layers of quartzite (2 1/2 ft of core)
94 ft	106 ft	Slate with layers of quartzite; some of slate sandy (6 ft of core)
106 ft	112 ft	Slate, real sandy, quite a number of white sandy layers mixed through

Appendix 7—Brief description of core from seven holes and two offset holes drilled by Franks in 1958 at Silver City Dome.

SILVER CITY DOME

Holes were logged by P. C. Franks, 1958

Hole No. 1M (Hill)

Location: sec. 32, T. 26 S., R. 15 E.

1200 ft E, 200 ft N of SW Corner

0 ft	765 ft	No core
0 ft	25 ft	No samples
25 ft	30 ft	Light-yellowish-gray and light-gray fine-grained limestone
30 ft	40 ft	Light-pinkish-gray fine-coarse-grained limestone
40 ft	52 ft	Very light brownish gray fine-medium limestone; small fossil fragments
52 ft	55 ft	Medium-gray argillaceous fine limestone; shaly partings
55 ft	80 ft	Medium- to light-gray; noncalcareous shale
80 ft	103 ft	Dark-greenish-gray fine-coarse lamproite
103 ft	111 ft	Dark- to medium-gray shale; shale is baked
111 ft	180 ft	Medium-light-gray and light-brownish-gray, fine-medium limestone; fenestellid fragments between 115–120 ft, 125–130 ft; lighter color below 120 ft; fossil fragments, bryozoans, brachiopods, between 145–150 ft; rock grades to medium-gray at 175 ft
180 ft	183 ft	Medium-gray argillaceous fine limestone
183 ft	230 ft	Medium-gray calcareous shale, small mica flakes
230 ft	252 ft	Medium-dark-gray calcareous shale
252 ft	255 ft	Medium-gray to medium-dark-gray fine limestone
255 ft	262 ft	Medium-dark-gray calcareous shale; small mica flakes
262 ft	275 ft	Medium-dark-gray and light-gray fine-medium argillaceous limestone; inter-laminated shale, 270–275 ft
275 ft	280 ft	Very light gray and medium-gray, mottled fine limestone
280 ft	310 ft	Very light gray, fine-medium limestone; chalky in top 5 ft
310 ft	323 ft	Light-gray fine limestone
323 ft	327 ft	Medium- to dark-gray calcareous shale
327 ft	342 ft	Medium-light-gray calcareous siltstone and sandstone. A few mica flakes
342 ft	348 ft	Medium- to dark-gray calcareous, silty shale
348 ft	350 ft	Light-gray fine limestone
350 ft	388 ft	Medium- to dark-gray, noncalcareous shale
388 ft	400 ft	Light-gray and light-brownish-gray fine limestone; oolitic; top has medium-gray organic, calcareous clay fragments, 388–390 ft; oolite fillings commonly leached out; some brachiopod fragments
400 ft	455 ft	Light-gray to light-brownish-gray mottled limestone; fine to medium; as above no oolites, trace fossil fragments (trace of chert and fossil fragments)
455 ft	468 ft	Light-gray and light-brownish-gray, medium- to dark-gray, fine limestone and shale. Shale is calcareous and brittle
468 ft	480 ft	Very light gray and light-brownish-gray fine-medium limestone
480 ft	488 ft	Light-gray and medium-dark-gray fine-medium limestone, some coarse limestone. Shale is non-calcareous. Fossils (*Composita* sp). About 30% shale
488 ft	495 ft	Very light gray to medium-light-gray, and very light brownish gray, fine-medium, and some coarse limestone
495 ft	520 ft	Very light gray and medium- to dark-gray, fine limestone, and shale. Trace of chert and muscovite flakes in the calcareous shale
520 ft	528 ft	Medium- to dark-gray calcareous and silty shale
528 ft	538 ft	Light-gray and light-brownish-gray; fine limestone, brachiopod fragments
538 ft	545 ft	Medium- to dark-gray shale
545 ft	553 ft	Light-gray and some light-brownish-gray; fine and coarse crystalline limestone
553 ft	558 ft	Medium to dark calcareous gray shale
558 ft	573 ft	Light gray; fine limestone
573 ft	579 ft	Medium- to dark-gray; silty calcareous shale. Some interbedded light-gray to light-brownish-gray limestone
579 ft	586 ft	Medium to gray fine-grained limestone; very hard

586 ft	633 ft	Medium- to dark-gray calcareous, silty shale. Thin limestone bed between 610–615 ft, very light gray, mottled brown; trace of coal
633 ft	645 ft	Medium-gray shale, limestone nodules; very calcareous; silty. Brown limestone nodules near top, some gas reported
645 ft	731 ft	Medium- to dark-gray and medium-gray shale, locally calcareous; some interbedded limestone at 633 ft. Trace of muscovite flakes
731 ft	735 ft	Medium-yellowish-brown, fine to coarse lamproite. Abundant phlogopite flakes up to 3 mm in diameter. Greenish-gray groundmass
735 ft	743 ft	Dark-gray shale; silicified?
743 ft	748 ft	Medium-yellowish-brownish to medium-brown and very light gray lamproite. Very light gray groundmass; phlogopite flakes ≤3 mm in diameter
748 ft	756 ft	Medium-dark-gray shale
756 ft	760 ft	Medium-yellowish-brown to medium-brown, very light gray lamproite; fine-coarse grained; very light gray groundmass; phlogopite flakes, ≤2 mm in diameter
760 ft	765 ft	Medium- to dark-gray and medium-yellowish-brown shale; locally silicified (?)
765 ft	774 ft	Gray pink, some mottled green; fine-coarse grained lamproite. Abundant phlogopite flakes, very soft, gray-pink groundmass, talcose(?); phlogopite flakes ≤2 mm in diameter
774 ft	775 ft	Gray, mottled-brown, fine-coarse grained lamproite; very abundant phlogopite flakes, some serpentine(?) blebs; very light gray groundmass; phlogopite flakes ≤3 mm in diameter
775 ft	795 ft±	Greenish-black; some brown-gray-mottled; fine-coarse grained lamproite; 30%± phlogopite flakes; some talcose(?) formations; some aragonite(?) veinlets; phlogopite flakes ≤4 mm

Hole No. 2M (Hill)
Location sec. 32, T. 26 S., R. 15E.
Center SW SE

0 ft	300 ft	No core
306 ft	501 ft	No core
0 ft	3 ft (?)	Soil
3 ft	20 ft	Light-yellowish-brown and light-gray fine-grained limestone; some coarse grained
20 ft	27 ft	Medium-gray calcareous shale
27 ft	36 ft	Light-gray fine-grained limestone; shaly partings(?)
36 ft	47 ft	Very light gray limestone, fine-medium
47 ft	50 ft	Very light gray, light-gray-orange limestone, fine-grained, mottled
50 ft	56 ft	Light-gray to light-yellowish-brown fine-grained limestone, mottled
56 ft	61 ft	Medium-dark-gray shale, noncalcareous
61 ft	68 ft	Greenish-black, very fineto fine lamproite, some phlogopite flakes
68 ft	111 ft	Medium-gray shale, locally calcareous near base
111 ft	118 ft	Very light gray and light-yellowish-brown, fine-medium limestone, mottled; fossil fragments, brachiopods, bryozoans
118 ft	130 ft	Medium to light-gray fine-grained limestone; some light-yellowish-brown between 125–130 ft
130 ft	140 ft	Medium-light-gray and light-brownish-gray; fine- to coarse-grained limestone
140 ft	165 ft	Light-gray fine limestone; argillaceous below 160 ft
165 ft	250 ft	Medium-gray shale; very calcareous to 195 ft; medium calcareous between 195–225 ft; very calcareous 225–259 ft
250 ft	275 ft	Dark- to medium-gray limestone; argillaceous
275 ft	285 ft	Very light gray to very light brown gray fine-grained limestone
285 ft	300 ft	Very light brownish gray fine-grained limestone; very soft
300 ft	301 ft	Gray-pink fine lamproite; abundant phlogopite flakes; calcareous groundmass; talcose(?); similar to core from 765–774 ft in hole No. 1M
301 ft	320 ft	Greenish-black fine lamproite; 30% phlogopite flakes; identical to unweathered Hills Pond lamproite; phlogopite flakes ≤1 mm in diameter; white calcite cuttings (aragonite?) from 315–320 ft
320 ft	345 ft	Medium- to dark-gray fine-grained limestone;
345 ft	350 ft	Medium-dark-gray shale; slightly calcareous
350 ft	360 ft	Pink-gray fine-grained limestone; trace of phlogopite flakes, soft, powdery cuttings
360 ft	391 ft	Medium-gray shale; locally calcareous; some interbedded limestone (?)
391 ft	395 ft	Medium-gray fine-grained limestone; cuttings very fine, similar to limestone from 579–586 ft in No. 1 M; very hard

395 ft	445 ft	Medium-light-gray, very light olive gray/light-gray–light-pink-gray, fine-medium-grained limestone; some interbedded medium-gray shale in top 5 ft
445 ft	450 ft	Medium-gray to medium-light-gray, and dark-gray, fine limestone and shale
450 ft	455 ft	Very light gray to light-brownish-gray limestone, fine-medium-grained. Some small hematitic limy nodules?
455 ft	467 ft	Light-olive-gray, fine-grained limestone. Some small hematitic limy nodules?
467 ft	471 ft	Light-brownish-gray to medium-dark-gray, fine-grained limestone
471 ft	477 ft	Dark-gray, noncalcareous shale
477 ft	485 ft	Light-gray very fine siltstone, some muscovite flakes; medium calcareous, some interlaminate(?) medium-gray shale
485 ft	490 ft	Medium-gray shale, some muscovite flakes, slightly calcareous
490 ft	505 ft	Light-gray siltstone, some muscovite flakes, medium calcareous, some interlaminate(?), medium-gray shale
505 ft	509 ft	Gray-black shale, noncalcareous; baked(?)
509 ft	520 ft	Light-brown, greenish-black lamproite, fine-medium-grained; small to medium green-black serpentine “eyes”; abundant phlogopite flakes; phlogopite is major constituent, flakes 1 mm in diameter; “eyes” ≤3 mm in diameter
520 ft	524 ft 5 inches±	Light-brown-greenish-black lamproite, fine-medium-grained; abundant green-black serpentine “eyes,” small white talcose formations (?) on fractures; small with aragonite(?) veinlets; abundant phlogopite flakes; phlogopite is major constituent, flakes ≤2 mm in diameter; “eyes” ≤3 mm in diameter

No. 3M (Hill)
Location: sec. 32, T. 26 S., R. 15 E.
50 ft north, 50 ft west, NE corner

73.5 ft		Rock bit; no core; no samples
73 ft 5 inches	106 ft8 inches	Fine-medium olive-gray to brown-gray lamproite; abundant greenish-black serpentine, pyroxene “eyes”; phlogopite flakes ≤1 mm in diameter; pyroxene“eyes” 3–5 mm in diameter; slightly weathered in upper 10 inches (?); basal 3 inches hard; phlogopite flakes give groundmass gray color locally

No. 4M (Hill)
Location: sec. 32, T. 26 S. , R. 15 E.
100 ft east, 100 ft north, SW

28 ft 4 inches		Rock bit; no core; no samples
28 ft 4 inches	30 ft 7inches	Fine-light-blue-gray to medium-greenish-gray lamproite; very calcareous; phlogopite flakes ≤ 1 mm in diameter; grades into lamproite below
30 ft 7 inches	42 ft 1 inches	Dark-greenish-gray lamproite, fine-grained, phlogopite flakes, locally medium calcareous; small inclusions of horizontal aragonite veinlets; phlogopite flakes ≤ 1 mm in diameter
42 ft 1 inch	42 ft 7 inches	Dark-greenish-gray lamproite, fine, small phlogopite flakes; medium-pink or calcite grains(?); very calcareous; phlogopite flakes <0.5 mm in diameter; basal contact wavy
42 ft 7 inches	46 ft±	Medium-gray, fine-coarse-grained limestone,; dense; fossiliferous
46 ft ±	54 ft	No core, no samples
54 ft	56 ft 5 inches	Pink-gray limestone, fine-grained; chalky; abundant solution pits; abundant wavy clay(?) formations (stringers)
56ft 5 inches	100 ft	Rock bit, no core, no samples

No. 5M (Hill)
Location: sec. 32, T. 26 S., R. 15 E.
100 ft east, 1275 ft north of SW

26 ft		Rock bit; no core; no samples
26 ft	29ft 3 inches	Dark-greenish-gray to brownish-gray; fine-medium-grained lamproite; abundant phlogopite flakes; abundant greenish-black serpentine “eyes”; partly weathered; phlogopite flakes 1 mm in diameter; serpentine “eyes” ≤ 3 mm in diameter

29 ft 3 inches	33 ft 8 inches	Very dark greenish gray lamproite; fine-medium-grained; abundant phlogopite flakes, abundant green-black serpentine "eyes"; some aragonite veinlets; some pyrite in veinlets; phlogopite flakes ≤ 1 mm in diameter; serpentine "eyes" ≤ 4 mm in diameter; aragonite at 32–33 ft ±; veinlets ≤ 0.1 ft thick, contain 1 mm pyrite crystals
33 ft 8 inches	34 ft 1 inches	Dark-gray shale; noncalcareous; thinly laminated; grades into limestone below
34 ft	37 ft 5 inches±	Medium-dark-gray to medium-light-gray, mottled limestone, fine-coarse-grained; fossiliferous; abundant interlaminated shale in top 0.3 ft

No. 6M (Hill)
sec. 32, T. 26 S., R. 15 E.
1330 ft east, 2745 ft north of SW Corner

23 ft		Rock bit; no samples
23 ft	27 ft	Light-brownish-gray to light-green-gray; fine-grained lamproite; phlogopite flakes ≤1 mm in diameter; eyes ≤ 5 mm in diameter, rock is very soft
27 ft	46 ft 3 inches	Dark-greenish-gray, fine-grained lamproite; abundant phlogopite flakes ≤2 mm; small white aragonite veinlets ≤1 mm thick; 30–40% serpentine blebs ≤5 mm in diameter; light-yellow-green "talcose" formations (stringers)
46 ft 3 inches	49 ft 4 inches	Dusky-yellowish-green to light-green, fine-grained lamproite; medium phlogopite flakes; abundant serpentine in ground mass; phlogopite flakes ≤1 mm in diameter
49 ft 4 inches	50 ft 3 inches	Light-brownish-gray, very fine grained lamproite, medium-gray to olive-green serpentine eyes; groundmass of very fine grained phlogopite flakes; "eyes" ≤7 mm in diameter; hard but noncalcareous; grades into next below
50 ft 3 inches	51 ft 5 inches	Light-brownish-gray to very light gray; very fine grained lamproite; small phlogopite flakes ≤0.5 mm in diameter; small serpentine blebs ≤2 mm in diameter, groundmass may be zeolitic; contact with shale below inclined 70°±. Very fine grained mica 0.5 inches from contact
51 ft 5inches	52 ft	Medium-light-gray shale, dusky-yellowish-green with white formations (stringers?); silicified(?); chloritized(?); hard

No. 7M (Hill)
sec. 32, T. 26 S., R. 15 E.
2650 ft east, 2745 ft north SW Corner

31 ft 5 inches		Rock bit; no samples
31 ft 5 inches	42 ft	Gray to olive-green to light-brownish-gray, mottled; fine-grained lamproite; abundant phlogopite flakes ≤1 mm in diameter; abundant dusky-yellowish-green serpentine eyes≤4 mm in diameter have phlogopite haloes from 32 ft to 33 ft±; some white clay(?) specks
42 ft	47 ft	Very light gray to light-brownish-gray, fine-grained lamproite, phlogopite flakes ≤1 mm in diameter; serpentine eyes gray-green, ≤3 mm in diameter, have phlogopite haloes
47 ft	52 ft 5 inches	Light-brownish-gray; fine-grained lamproite; serpentine eyes, blebs; abundant phlogopite flakes ≤2 mm in diameter; abundant serpentine eyes, blebs dark-greenish-gray, ≤3 mm in diameter

In the original description of the rocks:
S stands for either "small" or "some"
Peridotite is replaced by lamproite
Don't know what the abbreviation "Cs" stands for
Calc. stands either for calcareous or calcite

Appendix 8—Brief description of core from five holes drilled by Franks in 1958 at Rose Dome.

Rose Dome

DDH–1

sec. 13, T. 26 S., R. 15 E.
1875 ft north, 1157 ft west, SE corner sec. 13

3 ft±		Medium-white, light-gray, fine granite, largely rubble, not necessarily in place, highly weathered, slightly metamorphosed
3 ft	8 ft 5 inches±	Olive-gray, calcareous, very fine grained; slightly metamorphosed hornfels and shale; less metamorphosed with depth?
8 ft 5 inches	14 ft	Dark gray to light-gray very fine grained limestone, brittle-breaks with hackly to chonchoidal fractures; sugary texture in part, slightly metamorphosed?
14 ft	16 ft 5 inches	Soft-brown, yellowish-green fragments; bit dropped suddenly and drilling rate increased, some metamorphosed shale (hornfels) present; either altered mica rock or "granite"?
16 ft 5 inches	18 ft	Dark-gray, very fine grained limestone; some pyrite, dissemated and in veinlets; as from 9 to 14 ft?
18 ft	20 ft	Dark-gray to very light gray, very fine grained limestone; dolomitic in dark gray phases? Siliceous? In light-gray to very light gray patches; some calcite veinlets with iron-oxide staining and pyrite; argillaceous; basically no different than limestone above and below, possibly less cherty; hackly to chonchoidal fractures
20 ft	22 ft	Dark-gray to very light gray, very fine grained limestone, argillaceous(?), some silica in light-gray stringers(?) dolomite(?) in dark-gray areas; abundant pyrite in calcite veinlets and as replacement patches; some fossils, contorted laminated, some calcite veinlets, locally corroded with iron-oxide stain and chalky argillaceous filling, brittle hackly-chonchoidal fractures and not obviously recrystallized or metamorphosed

DDH–2

sec. 13, T. 26 S., R. 15 E.
1868 north, 1202 west, SE Corner sec. 13

0 ft	10 ft 8 inches	Rotary bit, no core
13 ft 9 inches	23 ft 7 inches	Cuttings saved
23ft 7	29 ft 8 inches	No core
43 ft 4 inches	44 ft 5 inches	No core
49 ft 1 inch	55 ft 9 inches	Rotary bit, no core

0 ft	0.6 inch	Soil derived from hnfls
0.6 inch	7 ft 5 inches	Dark-olive-gray to dark-yellowish-orange; very fine grained honfels, lime stain in fractures; highly fractured bedding seems inclined 30–45° WSW in sump pit
7 ft 5 inches	10 ft 8 inches	Yellowish-orange and very light gray, Cs and "Granite, some biotite; abundant granite fragments drilled up; seems to be highly altered "granite," "Gran" is fine grained with SC grains and some amphibole(?) needles and has abundant small voids filled with yellowish-orange limonite? Cs; many fragments show flow structure; "granite" is very light gray; core badly washed and worn
10 ft 8 inches	13 ft 9 inches	Dark-gray to green-black, very fine grained hornfels, trace of pyrite, limonite, and iron oxide on fractures. Cherty texture
13 ft 9 inches	23 ft 7 inches	Dark-gray to medium-gray and very light gray to yellowish-orange, very fine grained, hornfels, granite and Cs. Trace of pyrite and calcite on fractures. Cherty texture; seems to be decomposed granite in this interval; fine cuttings include yellowish to orange Cs, sericitic material and granite; quartz and feldspar.
23 ft 7 inches	29 ft 8 inches	Dark-gray, green-black, green-orange and brown-gray very fine grained, hornfels, mica rock selvage or stringers; some pyrite and calcite, probably in veinlets in hornfels; medium mica (phlogopite?) on some surfaces of hornfels; some quartz, feldspar and "granite" fragments from this interval may or may not be cavings; mica rock is brownish-gray to yellow-orange; yellow-orange is from altered phases; calcite matrix; some gray-green blebs and eyes; probably 50% present as veinlets and stringers cutting the hornfel
29 ft 8 inches	39 ft 1 inches	Medium-dark-gray very fine grained hornfels, locally gray to red near contact with mica rock next below; some mica flakes on fractured surfaces; apparently, as above, highly fractured and locally

		traversed by veinlets of calcite, pyrite and iron oxide that parallel fractures; bedding inclined as much as 60°±, or what looks like bedding, might be slaty cleavage; fractures commonly parallel to this direction as do color changes
39 ft 1 inches	43 ft 4 inches	Brownish-gray to gray-red, very fine mica rock; calcareous matrix; abundant pyrite veinlets and stringers, abundant calcite patches, veinlets, stringers, and masses; abundant medium-blue-gray calcareous serpentinitic “eyes” <4 mm in diameter hnfls and some 15% of rock entrapped in calcareous and mica matrix; abundant pyrite stringers and veinlets in calcareous masses (or limestone inclusions); contact with hornfels above may be present in interval from 39 ft 1 inches to 39 ft 5 inches, if so, highly irregular, locally near vertical, and with distinct sign of brecciation and calcification of country rock; abundant corroded limestone fragments, ≤1.5 cm diameter, in breccia along contact(?); some of the calcareous patches and stringers are as much as 1 ft long and may be inclusions of recrystallized limestone country rock; some angular rounded fragments of K-spar (rose “granite” type) as well as a few inclusions of calcified and fractured rounded inclusions of rose (?) “granite”
43 ft 4 inches	44 ft 5 inches	Mica-rock; as above in cored interval
44 ft 5 inches	55 ft 9 inches	Very light gray to medium-gray with brown overstones; some light-green- gray; limestone-marble, fine- to medium-grained; pyrite in mica rock veinlets and along argillaceous formations (stringers?), both gray-green and light-brownish-gray, fine pyrite blebs, pyrite also disseminated; some quartz crystalline in vugs; some disseminate phlogopite flakes in whole sequence; at least partly recrystallized in the upper 1 ft 5 inches± and cut by irregular veins of mica rock, some of which hold inclusions of pyritized hornfels; generally vuggy, vugs commonly lined with medium-coarse calcite crystals; mica-rock veinlets have medium-greenish-gray pyritic fringes composed largely of clay(?); vugs may be stained with oil; bedding seems inclined 60°± as are argillaceous formations (stringers?) and most vuggy stringers; loss of circulation in rotary bit interval from 49 ft 7 inches to 55 ft 9 inches indicates porosity or cavities; they may be extensive; hole bottomed because of reported loss of circulation; some vugs and fracs may show oil stain

DDH–3

Location: sec. 13, T. 26 S., R. 15 E.
1866 ft north, 1240 ft west, SE Corner sec. 13

0 ft	20 ft 8 inches	Rotary bit, no core
33 ft 1 inch	41 ft 5 inches	No core
54 ft 6 inches	76 ft 6 inches	Rotary bit
78 ft 2 inches	90 ft 1 inch	Rotary bit

5 ft		Dark-brownish-gray to dark-gray, soil and hornfels; largely from weathered hornfels; sump pit actually dug in hornfels
5 ft	7 ft (?)	Dark-brownish-gray, very fine hornfels; shaly bedding still seems to persist
7 ft	19 ft 9 inches	Yellow to dark-yellow-orange to medium-yellow-brown Cs; abundant very fine mica-flakes, quartz grains, and feldspar fragments; contains residuum of relatively fresh “granite”; seems to be weathered “granite” or otherwise altered “granite”
19 ft 9 inches	22 ft ±	Medium-light-gray, very fine grained “granite” or pegmatite; abundant calcite fragments in cuttings from 19 ft 9 inches to 20 ft 8 inches; trace of disseminated magnetite; pyrite veinlets and a few % of disseminated biotite books, ≤2 mm across; calcite and phlogopite probably from mica rock veins; locally highly fragmented with quartz and spar bound by medium-grained sericitic quartzo-feldspathic very fine grained matrix; quartz has typical opalescent character; “granite” is porphyritic, allotriomorphic, in equigranular, some subhedral phenocrysts
22 ft	26 ft ±	Light-gray to dark-gray, very fine grained hornfels; some very fine mica flakes, some iron-oxide stain; shaly bedding persists; trace of pyrite on fractures
26 ft	28 ft 7 inches	Medium-brown-gray, very fine to fine-grained mica rock; abundant calcite in matrix, abundant calcitic-chloritic veinlets, pods and masses; masses ≤7 cm in long dimension; phlogopite is major mineral component; many of the calcitic patches ≤1 cm across as well as larger ones; they may be either inclusions or replacement patches; abundant fragments of spar as inclusions and some rounded fragments of “granite” and abundant hornfels, ≤10 cm long, as inclusions
28 ft 7 inches	29 ft	Very light gray to medium-light-gray to medium-orange-pink, fine to very coarse carbonate; abundant disseminated very fine pyrite; small very fine mica flakes disseminated and as aggregates; composed mainly of calcite-interpenetration with mica rock above with irregular contact; medium-orange-pink is in irregular very fine patches ≤2 cm in long dimension

29 ft	29 ft 7 inches	Light-gray to dark-gray, very fine grained hornfels; some pyrite and iron-oxide on fractures, some very fine mica flakes; bedding poorly preserved; cherty texture; worn granite fragments recovered from this interval
29 ft 7 inches	31 ft 3 inches	Medium-brownish-gray. very fine to fine mica rock; abundant greenish-gray Co_3^{2-} chloritic eyes ≤1 cm in diameter; some calcite veinlets; trace of pyrite as replacements even in “granite” inclusions; grades into next below, but “granite” inclusions larger and more abundant than hornfels inclusions; “granite” inclusions saussuritized and have dark green-gray reaction rims against mica rock
31 ft 3 inches	32 ft	Mottled-dark-brown-gray to dark-black-gray, very fine to fine grained lamproite; abundant mica (phlogopite); trace of pyrite replacements; trace of $CaCo_3$ in matrix; grades into next above; medium feldspar and some “granite” inclusions ≤2 cm long; selvage against hornfels below is composed almost wholly of mica
32 ft	35 ft±	Medium-light-gray to dark-gray, very fine grained hornfels; iron-oxide stain on fractures; bedding preserved locally; fractured; cherty texture
35 ft	40 ft	Very light gray, dark-red medium-light gray-dark-gray and dark-black-gray, fine-medium and very fine calcareous mica rock or marble and hornfels; abundant to common calcite and phlogopite; trace of pyrite in calcareous mica rock; sequence could be altered limestone or marble and hornfels; medium feldspar and quartz fragments brought up in this interval, possibly inclusions from mica rock veins or stringers
40 ft	42 ft 6 inches	Light-gray to medium-gray and brownish-gray/white to light-gray, very fine to very coarse marble; abundant mica and pyrite in upper parts, disseminated pyrite less abundant in lower light (C) parts, quartz(?) in rims adjacent to mica rock inclusions; abundant mica rock blebs and inclusions or stringers, <5 cm long, in light (C) part. Small vugs in (C) parts; relict bedding(?) seems steeply inclined (60º±?), pyrite concentrated in veinlets and along metamorphosed shale parting in light lower part
42 ft 6 inches	46 ft	Medium-greenish-gray to medium-brownish-gray lamproite and mica rock, very fine grained; locally calcareous; small phlogopite in the lamproite; abundant phlogopite in mica rock and mica rock veins; abundant “granite” inclusions; some hornfels inclusions near base; cut by veinlets of calcareous medium-brownish-gray mica rock that hold abundant inclusions of hornfels, granite and feldspar “granite” inclusions in both lamproite and mica rock; veins highly saussuritized
46 ft	46 ft 7 inches	Dark-gray with green-black overtones, very fine grained hornfels; some pyrite along fractures; highly fractured; slaty to cherty texture
46 ft 7 inches	47 ft 8 inches	Medium-brownish-gray fine-grained mica rock; trace of disseminated pyrite; calcareous matrix; perhaps actually marble impregnated with phlogopite
47 ft 8 inches	50 ft 2 inches	White to light-gray marble; trace of disseminated pyrite and phlogopite; sugary texture; probably contains blebs or stringers of medium-brownish-gray mica rock judging by abundance of fragments in cuttings
50 ft 2 inches	52 ft 5 inches	Very light gray to medium-greenish-gray mica rock and pegmatite “granite”; ≤5% brownish-black biotite books probably chloritized; highly saussuritized particularly along contact with mica rock below; lower contact inclined 60 º±; porphyritic, allotriomorphic, inequigranular; quartz is opalescent in character but not abundant near contact with mica rock below
52 ft 5 inches	64 ft 2 inches	Fine-grained, medium-dark to brownish-gray mica rock; calcareous matrix, medium calcite blebs, light-gray-pinkish-gray-orange; abundant greenish-gray-dark-greenish gray blebs; some disseminated pyrite blebs and veinlets; pyrite most abundant near hornfels inclusions and where calcite is most abundant; phlogopite is major component; abundant inclusions of “granite,” feldspar, and contorted hornfels fragments; feldspar and “granite” inclusions highly saussuritized; inclusions <10 cm long; series of hornfels inclusions between 53 ft 6 inches and 54 ft 6 inches show parallel arrangement of relict bedding inclined 80º± from vertical and might be edge of a zone of interfingering of mica rock with shale; “granite” inclusions very abundant from 52.5–53.5 ft± and 59–63 ft±; calcite content of matrix is low from 53.6–55 ft and increases sharply near base
64 ft 2 inches	67 ft 7 inches	Very light gray to light-brownish-gray and dark-green-gray fine to coarse marble; small phlogopite flakes and dissemininated pyrite and blebs of pyrite; sugary texture; may contain blebs of calcareous mica rock
67 ft 7 inches	70 ft±	Medium-dark to brownish-gray mica rock, fine to very fine grained, calcareous matrix; some disseminated pyrite and calcite blebs? Generally as from 52 ft 5 inches to 64 ft 2 inches but no obvious inclusions seen in cuttings
70 ft±	73 ft 5 inches	White to light-gray and brown-gray to dark-greenish-gray marble, fine- to coarse-grained; small disseminated pyrite and phlogopite; sugary texture; may contain blebs and stringers of calcareous mica rock

73 ft 5 inches	78 ft 1 inch	Medium-dark brownish gray mica rock, fine-very fine grained; calcareous matrix, veinlets and blebs?; some green-gray blebs and eyes; trace of disseminated pyrite; very calcareous locally in basal 2 ft; "granite" and hornfels inclusions; pyrite seems most abundant where calcite is most abundant; hornfels inclusions become very abundant from 76 ft± to 78 ft 1 inches; locally may even be intercalated with hornfels in this interval; hornfels inclusions or veinlets cut by calcite veins
78 ft 1 inch	90ft 1 inch	Medium-dark-gray to medium-light-gray and medium-light-gray to medium-gray hornfels/shale, very fine grained; some calcite and pyrite veinlets fill fractures; locally calcareous; some disseminated pyrite; abundant very fine mica (musc?) flakes disseminated along laminae; yellowish-brown stringers and zones of hornfels near contact with mica rock above may be impregnated with phlogopite; cherty fabric and thin lam where not overly metamorphosed; change from hornfels to shale is in interval from 80 ft to 86 ft

DDH–4

1827 ft north, 1125 ft west, SE Corner sec. 13
sec. 13, T. 26 S., R. 15 E.

0 ft	12 ft 1 inch	Rotary bit, no core
0 ft	6 ft±	Dark-yellow-brown and medium-yellow-brown soil, Cs–C, slightly calcareous; abundant hematite; abundant quartz, feldspar, and "granite" and hornfels fragments; abundant sericitic mica in yellow-brown clay base of soil and sandy and gravelly clay residuum is best description; hornfels fragments seem to increase in abundance downward
6 ft±	11 ft±	Dark-yellow-brown and very coarse Cs and "granite" residue, abundant limonite stain; very abundant quartz, feldspar, and "granite" fragments in dark-yellow-brown medium sericitic clay matrix
11 ft±	12 ft 1 inch	Dark-gray-orange to yellow-orange, fine to medium "granite" residue; medium-bleached biotite or vermiculite; abundant limonite; slightly calcareous; trace of opaques; abundant Cs, gray-orange-yellow-orange; abundant quartz and feldspar grains; could be "granite" cut by stringer of weathered mica rock
12ft 1 inch	18 ft 5 inches±	Very light gray to light-gray fine to coarse "granite"; pegmatitic; ≤10% biotite; trace of magnetite and disseminated pyrite; some hornfels(?) inclusions; trace of hematite after magnetite(?); has numerous small vugs ≤3 mm in long dimension that are filled with a late generation of crystalline quartz; early quartz has bluish opalescent character; texture generally allotriomorphic, inequigranular to subequigranular; upper fine-medium-grained phase may show faint flow structures; plagioclase feldspar partly altered and shows green-gray tones; whole sequence shows some sign of weathering; much feldspar shows sign of graphic-vermicular intergrows with quartz; altered and weathered?
18 ft 5 inches±	19 ft 4 inches±	Dusky-yellow very fine to fine-grained Cs, abundant mica (bleached-vermiculitic); some black opaques; quartz, feldspar; some calcite; most likely highly weathered and altered mica rock
19 ft 4 inches±	20 ft 5 inches±	Very light gray to light-gray, fine to coarse "granite"; ≤10% biotite; trace of hematite after magnetic(?); generally as from 12 ft 1 inch to 18 ft 5 inches; some hornfels(?) inclusions; core badly worn; altered and weathered?
20 ft 5 inches±	22 ft 8 inches±	Dusky-yellow, very fine to fine weathered mica rock; abundant quartz and feldspar fragments, possibly inclusions; some calcite; very abundant bleached biotite or phlogopite
22 ft 8 inches±	24 ft 8 inches±	Very fine grained hornfels, medium-dark-gray with green overtones; commonly dark-gray along fractures; some calcite as fracture filling; trace of pyrite on fractures and also limonite and jarosite stain; cherty texture; highly fractured
24 ft 8 inches	38 ft±	Light-brown-gray to medium-green-gray, very fine to fine-grained mica rock/lamproite; small to medium calcareous matrix; lamproite has abundant accessory phlogopite and some black opaque grains; trace of pyrite concentrated on hornfels inclusions along calcite veinlets; abundant inclusions of altered feldspar to 1 cm in long diameter; small to medium hornfels inclusions ≤3 cm in long diameter; some hornfels inclusions cut by abundant calcite veinlets; abundant "zeolitic" eyes ≤2 mm in diameter in mica rock; lamproite is cut by steeply inclined veins of mica rock ≤2 cm thick; small quartz inclusions in mica rock and lamproite; small "granite" of hornfels inclusions in basal 4 ft of lamproite
38 ft±	42 ft 2 inches±	Medium-dark-gray to dark-gray, very fine grained hornfels; trace of small pyrite on fractures; some $CaCO_3$; some as minute veinlets associated with pyrite; cherty texture; fractured

42 ft 2 inches±	46 ft 5 inches±	Medium-dark-gray to dark-gray and brown-gray, very fine to very fine-fine hornfels and mica rock; hornfels and mica rock as above; seems to be intercalated hornfels and calcareous mica rock; about 40% mica rock
46 ft 5 inches±	49 ft 3 inches	Medium-dark-gray to dark-gray, very fine grained hornfels; trace of small pyrite on fractures; small $CaCO_3$, partly as veins; cherty texture; fractured

DDH–5

1720 ft north, 827 ft west, SE Corner sec. 13
sec. 13, T. 26 S., R. 5 W.

0 ft	24 ft	Rotary bit, no core
0 ft	5 ft 1 inch	Very fine grained hornfels, very dark gray to medium-gray; abundant iron-oxide stain; trace of mica flakes on some fracture surfaces along with abundant iron-oxide; cherty texture; relict laminae; hole collared in hornfels and soil derived from same
5 ft 1 inch	9 ft 8 inches±	Medium-yellowish-brown, very fine grained, pegmatitic “granite” residuum; small to medium sericite flakes; abundant iron-oxide stain; very small biotite and bleached biolite; quartzite and feldspar fragments in medium-yellowish-brown sericitic Cs matrix; highly weathered “granite”; abundant “granite” fragments
9 ft 8 inches±	17 ft 6 inches±	Dusky-yellow Cs; calcareous; abundant fine-bleached biotite or phlogopite flakes; medium hornfels, quartz, feldspar fragments with abundant phlogopite-bleached phlogopite flakes in calcareous Cs matrix; weathered mica rock or lamproite
17 ft 6 inches±	19 ft 4 inches	Medium-greenish-gray, very fine to fine grained lamproite; abundant phlogopite phenocrysts ≤1 mm in diameter; calcareous matrix; small black opaques; trace of disseminated pyrite; some calcite veinlets; cuttings of brownish-gray mica rock probably from veins cutting lamproite; matrix probably carries both clay and serpentine as well as calcite; some “granite,” quartz, feldspar, and hornfels inclusions
19 ft 4 inches	12 ft 5 inches±	Medium- to dark-gray very fine grained hornfels, abundant pyrite as veinlet filling; some calcite in veinlets; cherty texture; fractured; grades into limestone below by interlamination of increasing $CaCO_3$ content
12 ft 5 inches±	24 ft	Light- to medium-gray fine-grained limestone or marble; medium to abundant disseminated pyrite and pyrite in veinlets; some disseminated very fine phlogopite flakes; at least partly recrystallized; chonchoidal to hackly fracture; small quartz crystals in small vugs

In the original description of the rocks:
S stands for either “small” or “some”
Peridotite is replaced by lamproite
Don’t know what the abbreviation “Cs” stands for
Calc. stands either for calcareous or calcite

Appendix 9—Brief description of core from the Eagle 4 and Eagle 5 drill holes in Rose Dome.

Eagle 4

0 ft	43 ft	Casing
4 ft	43 ft 5 inches	Limestone
43 ft 5 inches	48 ft 8 inches	Weathered lamproite
48 ft 8 inches	49 ft	Altered limestone and mixed lamproite; lamproite has several calcite stringers
49 ft	49 ft 2 inches	Limestone
49 ft 2 inches	142 ft	Gray shale
142 ft	144 ft 5 inches	Very fossiliferous limestone and minor shale
144 ft 5 inches	144 ft 10 inches	Fossiliferous shale followed by limestone
144 ft 10 inches	150 ft 4 inches	Very fossiliferous limestone
150 ft 4 inches	157 ft 3 inches	Limestone mixed with shale, mostly concentrated in swirly thin bands up to several inches thick; stylolites are common
157 ft 3 inches	159 ft 5 inches	Fossiliferous limestone mixed with shale
159 ft 5 inches	166 ft 5 inches	Dark shale
166 ft 5 inches	170 ft 1 inch	Dirty fossiliferous limestone
170 ft 1 inch	171 ft 8 inches	Alternating thin limestone and shale layers
171 ft 8 inches	198 ft 3 inches	Dark hard shale, probably limy
198 ft 3 inches	201 ft 2 inches	Dirty fossiliferous limestone
201 ft 2 inches	206 ft 1 inch	Dark hard shale
206 ft 1 inch	206 ft 6 inches	Coaly, dirty limestone
206 ft 6 inches	216 ft 3 inches	Very fossiliferous dirty limestone with large crinoids; some intervals more shaly or limy
216 ft 3 inches	271 ft 4 inches	Top part has some shale breaks; limestone is clean, sugary, and has many stylolites
271 ft 4 inches	271 ft 6 inches	Coaly shale
271 ft 6 inches	275 ft 2 inches	Dense fossiliferous limestone
275 ft 2 inches	279 ft 2 inches	Silty to sandy brown-gray shale, some slight oxidation, top 4–5 inches is quite dark shale
279 ft 2 inches	300 ft 7 inches	Fine sand, siltstone wit thin shale breaks; lower 2 ft 1 inch mostly shale with siltstone breaks; some minor oxidation
300 ft 7 inches	300 ft 10 inches	Coal
300 ft 10 inches	313 ft 5 inches	Alternating fine sand siltstone and minor shale; some oxidation
313 ft 5 inches	314 ft 2 inches	Coal (Thayer coal)
314 ft 2 inches	314 ft 6 inches	Dark shale
314 ft 6 inches	317 ft 1 inch	Under clay with some limestone clasts, then becoming gray shale at the bottom
317 ft 1 inch	335 ft 6 inches	Light-gray laminated siltstone and shale, getting darker and mostly shale farther down; rock is quite hard, probably calcareous
335 ft 6 inches	342 ft 4 inches	Bluish-gray modeled limestone with some shale breaks, up to a few inches thick
342 ft 4 inches	343 ft 4 inches	Conglomeratic zone
343 ft 4 inches	399 ft 1 inch	Fossiliferous limestone, some cavities and several shale breaks from 3 to 10 inches thick
399 ft 1 inch	404 ft 9 inches	Mostly dark shale alternating with limestone
404 ft 9 inches	409 ft 3 inches	Metamorphosed limestone
409 ft 3 inches	451 ft 8 inches	Lamproite
451 ft 8 inches	452 ft 2 inches	Metamorphosed rock
452 ft 2 inches	452 ft 9 inches	Limestone
452 ft 9 inches	454 ft 9 inches	Dirty argillaceous fossiliferous limestone
454 ft 9 inches	463 ft 1 inch	Dark shale
463 ft 1 inch	463 ft 6 inches	Transition zone
463 ft 6 inches	466 ft 3 inches	Limestone
466 ft 3 inches	470 ft 4 inches	Dark shale
470 ft 4 inches	470 ft 9 inches	Transition zone
470 ft 9 inches	493 ft 4 inches	Limestone with a few shale interbeds, oil shows in the upper part of the core
493 ft 4 inches	495 ft 7 inches	Limestone with silty shale interbeds
495 ft 7 inches	497 ft 1 inch	Fossiliferous limestone
497 ft 1 inch	497 ft 10 inches	Dark shale
497 ft 10 inches	504 ft 9 inches	Tan-colored limestone with some shale interbeds, fossiliferous
504 ft 9 inches	506 ft 5 inches	Dark shale, some oil staining
506 ft 5 inches	523 ft 8 inches	Light-gray fossiliferous limestone, some oil staining, argillaceous in part

523 ft 8 inches	525 ft 3 inches	Dark shale
525 ft 3 inches	525 ft 9 inches	Conglomeratic layer, oil staining
525 ft 9 inches	527 ft 9 inches	Silty sandstone, some shale
527 ft 9 inches	547 ft 5 inches	Argillaceous fossiliferous limestone, some dark-gray shale interbeds (Dennis)
547 ft 5 inches	616 ft 5 inches	Mostly dark-gray shale, some lighter-colored silty layers (Galesburg?)
616 ft 5 inches	616 ft 6 inches	Light-pink-colored intrusive
616 ft 6 inches	617 ft 6 inches	Shale
617 ft 6 inches	618 ft	Metamorphosed, hard shale
618 ft	621 ft 6 inches	Pinkish lamproite intrusive
621 ft 6 inches	636 ft 6 inches	Mostly dark-gray shale
636 ft 6 inches	667 ft 5 inches	Alternating darker- and lighter-colored siltstone, showing fine laminations
667 ft 5 inches	660 ft	Light-greenish siltstone containing limestone clasts
660 ft	661 ft 11 inches	Light-colored fossiliferous limestone
661 ft 11 inches	666 ft 1 inch	Soft greenish siltstone or mudstone with limestone clasts
666 ft 1 inch	669 ft 8 inches	Dark-gray to black siltstone and shale
669 ft 8 inches	672 ft 4 inches	Siltstone with limestone clasts
672 ft 4 inches	673 ft 4 inches	Limestone with some siltstone shale layers
673 ft 4 inches	679 ft 6 inches	Silty shale with some limestone interbeds
679 ft 6 inches	680 ft 8 inches	Gray-green shale
680 ft 8 inches	682 ft 3 inches	Mixed limestone and shale
682 ft 3 inches	684 ft 3 inches	Shale
684 ft 3 inches	684 ft 11 inches	Mixed limestone and shale
684 ft 11 inches	687 ft 8 inches	Soft greenish shale
687 ft 8 inches	697 ft 10 inches	Stylolitic limestone; bottom 9 inches is a light-gray argillaceous limestone
697 ft 10 inches	697 ft 8 inches	Greenish shale
697 ft 8 inches	698 ft 2 inches	Dark-gray coaly shale
698 ft 2 inches	705 ft 3 inches	Greenish-gray shale containing limestone clasts that become larger and more frequent farther down; lower contact sharp
705 ft 3 inches	705 ft 5 inches	Soft greenish shale
705 ft 5 inches	768 ft 5 inches	Interbedded, crossbedded, fine-grained sandstone and gray shale and siltstone; lower 20 ft is mostly clean fine-grained sandstone
768 ft 5 inches	782 ft 1 inches	Fine-grained sandstone containing dark shale laminate
782 ft 1 inches	782 ft 5 inches	Fossiliferous limestone containing a ¼-inch pyrite-rich thin layer at the bottom
782 ft 5 inches	786 ft 5 inches	Lamproite, top and bottom several inches are dark-gray to black, while center has orange-brown color
786 ft 5 inches	789 ft 5 inches	Argillaceous limestone to siltstone; probably some coal at the contact with the lamproite, but it is very altered
789 ft 5 inches	794 ft	Argillaceous limestone or limy siltstone
794 ft	805 ft	Conglomeratic- or brecciated-looking limestone consisting of limestone clasts floating in a shale matrix (Lenapah?)
805 ft	809 ft 8 inches	Dense gray-brownish limestone with thin shale laminate
809 ft 8 inches	813 ft 6 inches	Mostly siltstone
813 ft 6 inches	817 ft 4 inches	Limestone with a shaly interval near bottom
817 ft 4 inches	830 ft 8 inches	Thinly laminated dark-gray to black shale
830 ft 8 inches	831 ft 10 inches	Rock looks like an underclay
831 ft 10 inches	841 ft 2 inches	Gray-greenish laminated shale containing one limestone clast
841 ft 2 inches	841 ft 8 inches	Soft dark-gray soft clay/shale
841 ft 8 inches	845 ft 2 inches	Dense light-gray limestone
845 ft 2 inches	846 ft 11 inches	Limestone grades into a gray shale
846 ft 11 inches	851 ft	Limestone with a few shaly intervals

Eagle 5

0 ft	36 ft 2 inches	Casing and cement
36 ft 2 inches	48 ft 7 inches	Gray stylolitic limestone
48 ft 7 inches	49 ft	Gray shale
49 ft	50 ft 2 inches	Argillaceous gray limestone
50 ft 2 inches	54 ft 8 inches	Lamproite
54 ft 8 inches	55 ft 2 inches	Dark-gray shale

55 ft 2 inches	148 ft 1 inch	Gray shale, maybe some ironstone concretions
148 ft 1 inch	163 ft 9 inches	Light-to-medium-gray limestone fossiliferous in places, contains shale laminae
163 ft 9 inches	173 ft 11 inches	Dark-gray hard shale, lower 5 inches is a dark fossiliferous limy shale
173 ft 11 inches	176 ft 3 inches	Limestone fossiliferous in part
176 ft 3 inches	205 ft	Laminated shale and siltstone; possibly some fine sand; laminae are wavy (Bonner Springs Shale)
205 ft	208 ft	Top 7 inches is very fossiliferous dark-gray limy shale, followed by limestone with wavy shale laminae
208 ft	218 ft 10 inches	Dark-gray shale
218 ft 10 inches	224 ft 11 inches	Very fossiliferous dark-gray limestone
224 ft 11 inches	233 ft 5 inches	Gray limestone with shaly intervals
233 ft 5 inches	235 ft 6 inches	Dirty, very fossiliferous limestone
235 ft 6 inches	278 ft 2 inches	Sugary, clean, stylolitic gray limestone; minor shale partings; vuggy in places
278 ft 2 inches	278 ft 4 inches	Black shaly interval
278 ft 4 inches	280 ft 6 inches	Clean gray limestone
280 ft 6 inches	281 ft 6 inches	Dark-gray shale
281 ft 6 inches	297 ft 2 inches	Alternating fine-grained sandstone, siltstone and shale; top 4 ft 3 inches are much more sandy
297 ft 2 inches	297 ft 10 inches	Dark-gray shale which may be coaly
297 ft 10 inches	318 ft 5 inches	Mostly fine-grained sandstone, with silty and shaly laminae; all sand is crossbedded and quite clean
318 ft 5 inches	319 ft 3 inches	Coal
319 ft 3 inches	337 ft 7 inches	Carbonaceous shale, underlain by laminated siltstone shale containing limestone clasts; followed by laminated siltstone and shale and changing to a dark-gray shale with minor siltstone
337 ft 7 inches	361 ft	Blue-gray limestone, several more shaly intervals that appear to be more fossiliferous; sharp contact with lamproite
361 ft	428 ft 1 inch	Lamproite, top 2 ft is oil stained
428 ft 1 inch	442 ft	Blue-gray limestone, containing some shaly intervals; stylolites are common
442 ft	442 ft 3 inches	Dark-gray to black shale
442 ft 3 inches	476 ft 7 inches	Mostly limestone, lithographic in places, stylolitic containing several 4–6 inches dark-gray shale intervals; limestone is discolored in places taking on greenish/pinkish color (oil?)
476 ft 7 inches	485 ft 2 inches	Dark-gray laminated shale
485 ft 2 inches	488 ft 8 inches	Very fossiliferous argillaceous light-gray limestone
488 ft 8 inches	494 ft 4 inches	Medium-gray sandy-to-silty limestone
494 ft 4 inches	497 ft 4 inches	Gray stylolitic limestone
494 ft 4 inches	498 ft 3 inches	Gray-green shale
498 ft 3 inches	516 ft 9 inches	Gray stylolitic limestone, some oil staining
516 ft 9 inches	530 ft	Fossiliferous argillaceous limestone; at 528 ft 8 inches some sphalerite
530 ft	530 ft 10 inches	Dark-gray shale
530 ft 10 inches	532 ft 8 inches	Gray limestone
532 ft 8 inches	536 ft 4 inches	Lamproite
536 ft 4 inches	532 ft 9 inches	Brownish-gray limestone metamorphosed near lamproite contacts
532 ft 9 inches	533 ft 2 inches	Dark-gray shale
532 ft 2 inches	539 ft 9 inches	Gray limestone having a “zebra-like” appearance, consisting of irregular patches of recrystallized coarser limestone mixed with finer-grained limestone; oil staining in upper 2 ft
539 ft 9 inches	545 ft 8 inches	Partially recrystallized limestone
545 ft 8 inches	550 ft 8 inches	Limestone containing shale breaks and large mollusks (Winterset)
550 ft 8 inches	552 ft 2 inches	Black shale, shale may have phosphate nodules (Stark)
552 ft 2 inches	559 ft 9 inches	Gray very fossiliferous shale changing to light-gray limestone, last 9 inches is a more argillaceous limestone, oil staining on fracture surfaces
559 ft 9 inches	560 ft 11 inches	Mixed limestone, shady limestone and shale
560 ft 11 inches	561 ft 5 inches	Dark-gray shale
561 ft 5 inches	569 ft 10 inches	Mixed limestone, shady limestone, and shale
569 ft 10 inches	579 ft 8 inches	Mostly shale with few limy intervals near top
579 ft 8 inches	656 ft 9 inches	Gray shale, quite a bit of pyrite in the upper part
656 ft 9 inches	656 ft 11 inches	Fossiliferous limy shale
656 ft 11 inches	658 ft 9 inches	Gray shale
658 ft 9 inches	659 ft 4 inches	Gray-green shale containing some limy clasts
659 ft 4 inches	661 ft 4 inches	Gray-green shale
661 ft 4 inches	681 ft 6 inches	Laminated gray shale; minor siltstone
681 ft 6 inches	683 ft 10 inches	Gray limestone
683 ft 10 inches	688 ft 8 inches	Limestone with green and gray shale breaks
688 ft 8 inches	690 ft 2 inches	Fossiliferous shale containing some limestone clasts

690 ft 2 inches	698 ft 6 inches	Mostly shale with limestone clasts of all sizes
698 ft 6 inches	700 ft 1 inch	Mostly gray limestone (Tacket)
700 ft 1 inch	708 ft 6 inches	Mostly laminated gray shale
708 ft 6 inches	709 ft 7 inches	Predominately limestone
709 ft 7 inches	712 ft 10 inches	Gray-green shale, minor limy breaks
712 ft 10 inches	722 ft 5 inches	Stylolitic limestone containing minor shale laminae
722 ft 5 inches	723 ft 5 inches	Gray-green shale
723 ft 5 inches	724 ft 3 inches	Dark-gray to black shale
724 ft 3 inches	726 ft 9 inches	Limestone with irregular shaly patches
726 ft 9 inches	727 ft 9 inches	Gray-green shale
727 ft 9 inches	730 ft 11 inches	Limestone mixed with shaly patches
730 ft 11 inches	757 ft 1 inch	Laminated fine-grained sandstone, siltstone, and gray shale
757 ft 1 inch	757 ft 2 inches	Coaly interval
757 ft 2 inches	760 ft	Dark-gray shale in part coaly
760 ft	797 ft 10 inches	Laminated crossbedded micaceous fine-grained sandstone, siltstone, and shale
797 ft 10 inches	801 ft 9 inches	Gray to brown fossiliferous limestone (crinoids)
801 ft 9 inches	802 ft 11 inches	Dark shaly coal with a 4-inch lamproite in middle; gas bubbles coming from coal above lamproite
802 ft 11 inches	807 ft 6 inches	Gray-green shale with limestone clasts in lower part
807 ft 6 inches	812 ft 3 inches	Brownish-gray dense lithographic limestone
812 ft 3 inches	819 ft 7 inches	Nodular mixed gray-green shale/limestone unit
819 ft 7 inches	825 ft 1 inch	Dense brownish-gray stylolitic limestone
825 ft 1 inch	826 ft 8 inches	Dark-gray to black shale
826 ft 8 inches	826 ft 10 inches	Limestone
826 ft 10 inches	829 ft 2 inches	Dark-gray shale
829 ft 2 inches	832 ft 11 inches	Predominately limestone with a 223-inch very fossiliferous darker unit near the bottom
832 ft 11 inches	834 ft 10 inches	Dark-gray to black nodular shale
834 ft 10 inches	835 ft 4 inches	Dark-gray shale
835 ft 4 inches	835 ft 10 inches	Gray fossiliferous limestone
835 ft 10 inches	845 ft 10 inches	Dark-gray shale
845 ft 10 inches	846 ft 7 inches	Dark argillaceous fossiliferous limestone
846 ft 7 inches	857 ft 1 inch	Gray laminated silty shale containing some limestone clasts
857 ft 1 inch	857 ft 2 inches	Black shale
857 ft 2 inches	875 ft 11 inches	Stylolitic gray limestone, some argillaceous intervals
875 ft 11 inches	877 ft 9 inches	Dark-gray shale, some poorly developed underclay
877 ft 9 inches	882 ft 6 inches	Limestone
882 ft 6 inches	884 ft	Dark-gray shale containing some concretions
884 ft	886 ft	Some sandy “underclay looking” material
886 ft	890 ft 2 inches	Sandy limestone turning to a very fine grained sandstone
890 ft 2 inches	892 ft	Very fine grained sandstone, siltstone with limy nodules the first 1 ft 10 inches, changing to a laminated crossbedded shale siltstone with minor limy intervals and nodules
910 ft 4 inches	910 ft 5 inches	Lamproite
910 ft 5 inches	920 ft 3 inches	Very fine grained laminated sandstone, siltstone, and shale with minor limy intervals
920 ft 3 inches	928 ft 5 inches	Gray-brown silty shale
928 ft 5 inches	928 ft 7 inches	Dark-gray shale containing pyrite
928 ft 7 inches	929 ft 3 inches	Mixed fossilliferous shale and limestone
929 ft 3 inches	931 ft 6 inches	Laminated silty shale
931 ft 6 inches	932 ft	Fossiliferous lime mudstone
932 ft	934 ft 8 inches	Laminated shale
934 ft 8 inches	936 ft 7 inches	Medium-grained sandstone. Minor gas show
936 ft 7 inches	937 ft 2 inches	Laminated shale
937 ft 2 inches	948 ft 7 inches	Fine- to medium-grained sandstone, some grading to siltstone or shale, thin- to medium-bedded. Some soft-sediment deformation, gas shows throughout and some oil staining in the lower part
948 ft 7 inches	950 ft 2 inches	Sandstone as above. Some rip-ups. Gas shows
950 ft 2 inches	984 ft 4 inches	Black to gray laminated, thin-bedded sandstone, siltstone, and shale. Some burrowing and graded couplets. Minor (1–2-inch) brown limy fossiliferous beds and some small limestone nodules near the bottom of the interval
984 ft 4 inches	985 ft 3 inches	Coal
985 ft 3 inches	987 ft	Poorly developed underclay
987 ft	992 ft 3 inches	Laminated siltstone and shale. Some nodules in the top few inches

Appendix 10—Brief description of core from drill holes NP–1 through NP–3 located between Silver City Dome and Rose Dome, together with graphic logs of the lithologies encountered.

Hole NP–1

Nelson Pringle Property
NW NW sec. 26, T. 26 S., R. 15 E., Woodson County

0 ft	14 ft 9 inches	Casing
14 ft 9 inches	20 ft 8 inches	Orange-brown siltstone/shale
20 ft 8 inches	24 ft 8 inches	Very fine grained gray sandstone, probably little orange-brown in places
24 ft 8 inches	74 ft 4 inches	Gray shale alternating in some places with thin (.5–1-inch) siltstone laminate
74 ft 4 inches	80 ft 8 inches	Limestone contact with the shale above is sharp
80 ft 8 inches	82 ft 8 inches	Dark shaly or silty limestone in lower part with rounded clasts of limestone float in the shaly material
82 ft 8 inches	87 ft 11 inches	Limestone with many irregular shale stringers and clasts of limestone floating in shaly material
87 ft 11 inches	131 ft 2 inches	Limestone, clean and dense in places stylolitic, some vugs
131 ft 2 inches	138 ft	Limestone becomes increasingly more shaly and has a fairly sharp contact with shale below (Vilas?)
138 ft	147 ft 3 inches	All shale, top 1 ft 3 inches has some dark-brown-red coloration to it, so has the interval from 142 ft 3 inches to 144 ft 9 inches, shale is silty and quite competent over most of the interval, probably calcareous
147 ft 3 inches	156 ft 11 inches	Gray silty shale, towards the bottom 1–2-inch-thick more calcareous light-gray bed
156 ft 11 inches	162 ft	Gray silty shale
162 ft	168 ft	Shale, mixed shale and siltstone, siltstone is micaceous and has thin intervals of lighter-colored calcareous material
168 ft	188 ft 1 inches	End of hole

Hole NP–2

0 ft	7 ft	Surface casing
7 ft	17 ft	Brown weathered shale
17 ft	29 ft 1 inch	Gray micaceous siltstone and shale
29 ft 1 inch	63 ft 7 inches	Finely laminated gray shale
63 ft 7 inches	70 ft 3 inches	Very soft clay-like gray shale, bottom 2 inches is siltstone or fine-grained sandstone
70 ft 3 inches	79 ft	Limestone

Hole NP–3

0 ft	6 ft 7 inches	Casing
6 ft 7 inches	11 ft 7 inches	Weathered silty shale
11 ft 7 inches	30 ft 11 inches	Very fine grained sandstone to siltstone, orange-brown-weathered color in the upper part
30 ft 11 inches	94 ft 10 inches	Gray siltstone and shale, sharp contact with limestone
94 ft 10 inches	100 ft 9 inches	Dense crystalline limestone
100 ft 9 inches	101 ft 9 inches	Very calcareous dark shale (Rock Lake)
101 ft 9 inches	109 ft 1 inch	Limestone which is partially broken up and laced with shaly stringers and patches