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GEOLOGY OF THE NAMPA-CALDWELL AREA, WESTERN SNAKE RIVER PLAIN, IDAHO

By

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INTRODUCTION

The cities of Nampa and Caldwell lie within the western Snake River Plain where warm waters have been encountered by some irrigation wells and by all deep wells drilled for oil and gas exploration. This study was undertaken to map the surficial geologic units and to review available subsurface geologic data to obtain information on subsurface aquifers and structures likely to yield hot water for industrial, municipal and residential use.

The Nampa-Caldwell area lies in the broad, relatively flat alluvial valley of the lower Boise River. Maximum relief is about 100 m. The mapped area ranges in elevation from 2320 ft (707m) to 2700 ft (822m). The underlying geologic units are poorly exposed. Maximum exposed section is about 100 meters of Plio-Pleistocene sediments in the southwest corner of the Lake Lowell 7½-minute quadrangle.

Very little geologic mapping was available for the Nampa-Caldwell area, largely because of poor exposure of geologic units. Earlier geologic work by Lindgren and Drake (1904) and Savage (1958) was largely of a reconnaissance nature and little attention was paid to faulting and minor deformation features. Names of mapping units of Savage (1958) are used where possible in this report, but some stratigraphic units are provisionally redefined because they are new or they were not used in a consistent way by earlier workers. The emphasis of this study was to produce a 1:24,000 geologic map of the Nampa, Middleton, Caldwell, and Lake Lowell 7½-minute quadrangles. Mapping utilized the limited exposures in road cuts, river banks, and gravel quarries. The numerous water-well driller's logs on file at the Idaho Department of Water Resources were used to delineate the near-surface basalts, and obtain information on the stratigraphy of the uppermost layers.

The useful aspects of this study with regard to geothermal evaluation are the correlations of well logs and a summary of subsurface temperature information on Plate II . The 1:24,000 maps show a great deal of faulting in the plain in the southern part of the map area. These faults may influence the upward migration of geothermal waters into the shallow aquifers.

The Western Snake River Plain is a deep graben filled with volcanics and sediments of Cenozoic age. Total thickness of basin fill is known to exceed 4.2 km. from the deep exploratory well near Meridian, Idaho. Granitic rocks are exposed along the northeast and the southeast margin of the plain. The granitic rocks are partially covered by a veneer of volcanic and sedimentary rocks of late Cenozoic age. The late Cenozoic rocks are down tilted and down faulted toward the Snake River Plain. Some of the volcanic and sedimentary rocks are correlative with subsurface units in the plain beneath Nampa and Caldwell.

A major gravity high trends northwest-southeast through the northern part of the map area (Fig. 1). Oil and gas exploration wells have shown that this gravity high is associated with structurally high basalt with at least 700 m of structural relief (Plate II). This feature appears to be a large basalt horst, flanked by deep basins to the northeast and southwest. The high is underlain by a 2100 m section of interbedded basalt flows and sediments. Basalt comprises 1300 m of the 2100 m section(Fig.2).

The uppermost basalt is the Pliocene Grassy Mountain Formation and the remainder of the basalt is probably Miocene in age, but it cannot be clearly correlated with a known section on the margin of the plain.

The nature of the basins to either side of the horst is not well known. Our best information comes from the 1.4-km deep well drilled on the edge of the gravity high, northeast of Caldwell with penetrated a thick sequence of siltstone(probably all of Pliocene age) (Plate II).

Basalts of the Snake River Group are in the shallow subsurface over much of the area, but they are relatively thin. The total thickness in the Nampa Caldwell does not appear to exceed 30m. These flows are confined to the valley of Indian Creek and the topographic low now filled by the Lake Lowell reservoir (Plate I).

STRATIGRAPHY

General Statement

The thickness of Cenozoic volcanic and sedimentary fill in the western Snake River Plain is at least 4.7 km as demonstrated by the section penetrated by the exploratory well drilled near Meridian, Idaho. Basement rock was not penetrated. Because granitic rocks of the Idaho Batholith and associated metamorphic rocks occur in the mountains north and south of the plain (Taubeneck, 1971; Ekren et. al., 1978, and Fig. 1 of this report), it is commonly supposed that these rocks comprise basement beneath the plain. Although Challis volcanics have not been encountered in deep wells, it is likely that Challis volcanics and associated sediments lie deep in the subsurface, beneath the plain. Numerous northeast striking porphyry dikes of intermediate to silicic composition invade the granitic rocks along the north margin of the plain. These porphyries have been dated at 40 to 42 ± 10 million years by the Lead-alpha method in the Lowman area(Jaffe et. al., 1959 quoted in Armstrong, 1974). The Challis volcanic sequence is at least 1200 m thick in the central Idaho Mountains and may be as thick as 3200 m (Cater, et. al.,1973). Challis-aged volcanics are also mapped in the eastern Owyhee Mountains by Ekren et. al.(1978) where they may be greater than 300 m thick.

In this report, the subsurface stratigraphy expected in the Nampa-Caldwell area is based upon the lithologic and

and geophysical logs of the 4.7-km deep Meridian well(J.N. James No. 1). Some rock units similar to those encountered in the well are described from exposures at a number of localities on the margins of the plain by Malde and Powers(1963), Kittleman et. al. (1965), and Ekren et. al. (1978). Correlation of subsurface units to exposed sections can be made for some distinctive lithologic units, but a number of units do not have obvious counterparts exposed on the margin. No detailed stratigraphic work or geologic mapping has been published on the northeast margin of the plain. It is futile to attempt correlations to units that were only loosely defined in mapping by Lindgren(1898), Lindgren and Drake(1904), and Savage (1958 and 1961). Type sections and good stratigraphic descriptions have never been published for the Payette Formation, the Columbia River Basalts, and the Idaho Group in this area. Many of the late Cenozoic fluvial and lacustrine units are very similar in appearance and have been incorrectly correlated based on appearance rather than detailed geologic mapping. Correlation is further complicated by numerous facies changes within sedimentary units such as described by Malde and Powers(1963) in the Glenns Ferry Formation in the region east of this study area.

Stratigraphic Units

Older Andesite, Latite, and Dacites. The volcanic section encountered in the lowest 300 m of the J.N. James No. 1 well (Fig. 2) is described as flows and tuffs of Latite and Andesite with interbedded vitric and lithic tuffs. Volcanics of intermediate composition occur in the Reynolds Creek and Salmon Creek drainages and elsewhere within the Owyhee Mountains (Ekren, et al., 1978). Presence of biotite and amphibole phenocrusts in dacite dikes is reported by Pansze (1973) in the War Eagle Mountain area. While a correlation cannot be made, descriptions of the well cuttings suggest counterparts to this unit may exist the older Miocene (?) volcanics mapped by Ekren et. al., (1978) some of which rest upon an irregular granite surface in the Owyhee Mountains.

Older Owyhee Rhyolites and Welded Tuffs. The next 200-m section in the well contains rhyolitic rocks, described as gray to lavender welded tuffs that contain spherulites. Because this unit is overlain by sediments that are clearly the Sucker Creek Formation, these rhyolites probably have counterparts in the numerous rhyolites beneath the Sucker Creek Formation and correlative rocks in the Silver City area. The Silver City rhyolite of Bennett (1975) has a thickness of 200 m+, and a number of these rhyolite units mapped by Ekren et al. (1978) match the descriptions of the well cuttings remarkably well. K-Ar dating on the Silver City Rhyolites yielded ages of 15.6-15.7 ±0.4 million years (Pansze, 1979).

Lower Sucker Creek Formation. The 815 m section of brown clay and siltstone, and interbedded welded and non-welded ashy tuffs encountered in the well is very similar to the 180 m type section of the Sucker Creek Formation described by Kittleman et al. (1965). The uppermost 65 m of this unit in the well is logged as white to cream colored, poorly sorted, fine- to coarse-grained tuffaceous sandstone and minor interbedded brown siltstone. Character of this unit on electrical logs indicates poor permeability. The type section is exposed along Sucker Creek, 55 km southwest of the Meridian well. The section in Sucker Creek Canyon is described as altered tuffs, yellowish-gray clayey sandstones, vitric tuffs, arkosic sandstones, granite pebble conglomerate, and brown carbonaceous volcanic shale. The base of the unit is not exposed. In the vicinity of Owyhee Reservoir Kittleman et al. (1965) indicate the formation may be about 500 m thick. Ekren et al. (1978) mapped the Sucker Creek Formation along the Oregon-Idaho Border north to the vicinity of Homedale where it is covered by younger units.

Along the northeast margin of the Snake River Plain, much of the area mapped as Payette Formation by Lindgren (1898, p. 632), Kirkham, 1931, and Savage (1958 and 1961) may be correlative with the Sucker Creek Formation; however, mapping and stratigraphic correlations necessary to establish continuity or contemporaniety of the formations has not been attempted to date. Kirkham (1931) defined the Payette formation as the silty and clayey sediments that interfinger with basalts of the Columbia River Group in the vicinity of Horseshoe Bend and Weiser. McIntyre (1976) found that much of the sediment identified as Payette Formation by Kirkham was, in fact, overlying the basalt in this region and was younger.

Age of the Sucker Creek Formation is late Miocene based upon Barstovian mammalian fossils collected near the type locality and middle Miocene based on flora of Mascall age (Kittleman, et al., 1965, p. 7). A basalt within the Sucker Creek Formation yielded a potassium-argon age of 16.7 m.y. (Evernden and James, 1964, p. 971). The age assignments are consistent with four potassium-argon ages on the overlying Owyhee Basalts (Bryon, 1929) obtained by Watkins and Baksi (1974, p. 173) that ranged from 13.1 to 13.6 m.y.

Upper Sucker Creek Formation (?) and Owyhee Basalts (?). Above the lower Sucker Creek Formation is a 540-m-thick unit containing 200 m of massive greenish-black basalt flows in its lower part and interbedded black basalt flows, welded and non-welded tuffs, brown siltstones, and arkosic, moderately-sorted, sandstones in its upper part. The top of this unit has been called the top of the Sucker Creek Formation by geologists on the J.N. James No. 1 well of Meridian. It is tempting to correlate the massive basalt flows with the 400-m-thick section of Owyhee Basalts exposed near Owyhee Dam (Bryan, 1929) 60 km west of the well. These basalts are overlain by the Deer Butte Formation of Kittleman et al. (1965) in that area. At this point, correlation of the well section with units mapped on the margins of the plain is no longer clear. While the massive basalt flows probably correlate with the Owyhee Basalts, the section from 2700-1400 m containing interbedded basalt flows and sediments has no obvious counterpart. The interbedded basalts and sediments over the Owyhee Basalts (?) also contain a colorful welded tuff unit. Overall, this unit bears similarities to the "Silicic volcanic rocks" and parts of "the Columbia River Basalt", and the "Deer Butte-Poison Creek" formations discussed bv Newton and Corcoran (1963).

In the type section of the Owyhee Basalts, the Jump Creek Rhyolite of Kittleman et al. (1965) appears to overlie the basalts, but the actual age relationship of the Jump Creek Rhyolite to the Sucker Creek Formation is uncertain (Kittleman, 1978, Written Communication). The Jump Creek Rhyolite has been mapped over much of the western Owyhee Mountains by Ekren et al. (1978). The rhyolite directly overlies the Sucker Creek Formation but it has not been related to the Owyhee Basalts in this area. The colorful welded tuff described in the well at 2550 m depth may be the Jump Creek Rhyolite. A potassium-argon date on sanidine in the Jump Creek Rhyolite of the Owyhee

Mountains gave an age of 10.9$\pm$0.2 m.y. (Neill, 1975). There are a number of other welded rhyolite tuffs in the Owyhee Mountains which also yielded ages between of 9 to 10 m.y. (Neill, 1975 quoted in Ekren et al., 1978).

The upper 240 meters of the unit bears similarities to rocks mapped on the Deer Butte Formation by Kittleman et al. (1965), that overlie the Owyhee Basalts. In the well, basalt flows constitute about 140 m of the upper 240 m. The 290 meter type section at Deer Butte and Mitchell Butte 50 km due west of the well is described as altered volcaniclastic rocks, extrusive olivine basalts, arkose sandstone, and granite cobble conglomerates. Olivine basalts occur interbedded with volcaniclastics in the lower half of the type section. The upper half of the type section is mostly grayish-orange volcanic sandstone and interbedded claystone and siltstone. Kittleman et al. (1965) suggest that the Deer Butte Formation may have an aggregate thickness of 900 m. west of Owyhee Reservoir.

The Deer Butte Formation may be laterally contiguous with the Poison Creek Formation (Kittleman et al., 1963) mapped by Ekren et al. (1978) on the north flank of the Owyhee Mountains and along the north side of the Snake River Plain (by Savage, 1958 and 1961). No correlation has been established across the Snake River plain. On the north side of the plain, units mapped as the Poison Creek Formation overlie a thick section of basalt along the Payette River by the Black Canyon Dam. In this area the so called "Poison Creek Formation" is a moderately to well sorted arkosic sandstone and conglomerate unconformably overlain by the predominantly arkosic sands of the Idaho Group.

In the Meridian-well section, within the Columbia River Group (?) is a 150-m section of sand which is silica cemented in part. This sand unit lies within the thick basalt section rather than above it, but is otherwise quite similar to sediments mapped as the Poison Creek Formation.

Basalts and Interbedded Sandstones of the Columbia River Group (?) and the Banbury Basalts (?). Overlying the sediments tentatively assigned to the Deer Butte Formation is an 880-m section of black to dark green, altered and unaltered, partly zeolitized basalt with interbedded white, gray-white, poorly sorted sandstones and brown siltstones. Thick basalt flows constitute roughly two-thirds of the section. It is difficult to reconcile this predominantly basaltic unit with stratigraphy established to the west by Kittleman et al (1965) or on the east by Malde and Powers (1963). The Banbury basalts of Stearns (1936, p. 435) are in a similar stratigraphic position. Type locality for the Banbury basalts is 200 km east of the well, but Malde and Powers (1963, p. 1204) described faulted and decomposed basalt near Murphy, about 45 km south of the well, that they consider stratigraphically equivalent to the Banbury Basalt. Malde and Powers (1963) also identify Banbury Basalt on the north side of the Snake River Plain in the eastern Mount Bennett Hills which gave a whole-rock potassium-argon age of 13.5±1.5 m.y. (Armstrong et al., 1975). Other whole rock potassium-argon dates on the type Banbury Basalts yielded ages ranging from 3.5 to 4.9 m.y. (Armstrong et al. 1975, p. 230) suspect these young ages are invalid because of argon loss. Because of major inconsistencies in the K-Ar dating of the Banbury, Armstrong et al. (1975, p. 239) conclude that the name Banbury basalt has been used to designate basalts of several ages sandwiched between older silicic volcanic rocks and younger units, and the unit cannot be correlated as widely as was once proposed.

The stratigraphic position of this thick basalt sequence in the well may also correlate with the undescribed and unmapped sections of basalt north of the plain. James Fitzgerald(University of Idaho) is currently working on the geology and geochemistry of basalts in the Weiser embayment for a Ph.D. project, and hopefully stratigraphic information derived from his study will help identify these subsurface basalts.

Grassy Mountain Formation. The 880-m thick basalt section is overlain by a predominantly basalt unit 520 m thick. This unit contains arkosic white sands, welded and non-welded tuffs and siltstones in its lowermost 180 m. Tarry black hydrocarbons in the arkosic sands in the interval 3974 to 4285 feet (1211 to 1303 meters) were drill-stem tested in the Meridian well and yielded 60 bbl water per hour (2.8 liters/sec)(no temperature data released). The overlying 340 m of olivine basalts and minor interbedded tuffs and sandstones, claystones, and siltstones match the type section of the Grassy Mountain Formation described by Kittleman et al (1965). The type section is described as 335m of gray volcaniclastic rocks overlain by basalts with abundant labradorite, clinopyroxone and olivine. The Grassy

Mountain Formation is assigned an early to middle Pliocene age on the basis of Clarendonian and Hemphillian mammalian fossils (Kittleman et al., 1965).

Fossil ages from the Chalk Hills Formation of Malde (1963) are also of middle Pliocene age. The Chalk Hills Formation is mapped in the vicinity of Bruneau as lacustrine and fluvial sand silt and clay with diatomite, and numerous thin beds of vitric ash and sparse basaltic tuff. (Malde et. al, 1963, Ekren et al., 1978). Westward from the Murphy area Ekren et al. (1978) have not been able to differentiate the Chalk Hills Formation from the Poison Creek Formation, and have mapped similar fine and tuffaceous sediments as the Poison Creek Formation. In the Murphy area these sediments are interbedded, peripheral to, and intruded by ophitic olivine basalts of the Murphy area. Ekren et al. (1978) also map subaerial and subaqueous flows northwest of Sinker Creek that are associated with these sediments. Rhyolitic tuffs identified in the well may also correlate with rhyolite vitrophyre northwest of Sinker Creek described by Ekren et al., 1978. Both the rhyolite tuff in the well and the rhyolite vitrophyre are stratigraphically the youngest rhyolites in this region.

Thus it appears that a part of the Chalk Hills and Poison Creek Formations and some of the associated olivine basalts may be in part correlative with the Grassy Mountain Formation, and that these sediments have been intruded by olivine basalt.

<u>Chalk Hills Formation (?)</u>. The Chalk Hills Formation of Malde and Powers (1963) is a lacustrine unit exposed in the Bruneau area where it overlies the Banbury Basalts. Exposures eastward along the south edge of the Snake River Plain are poor, and age relationship of the Chalk Hills Formation to the Poison Creek Formation is obscure (Ekren et al., 1978). An earlier discussion pointed out that the Chalk Hills Formation could be, in part, correlative with the lower part of the Grassy Mountain Formation, and could interfinger with the basalts and also overlie the basalts of the Grassy Mountain Formation. Immediately overlying the Grassy Mountain Basalt in the Meridian well is a 200 m layer of gray-green siltstone (Plate II). The siltstone is faulted in the Meridian well and the section in that well is shortened about 90 m. True thickness of 200 m of siltstone occurs in the log from the Higgens n No. 1 well 8 km south. Although this siltstone is easily recognized in the geophysical logs of the wells as being between the Grassy Mountain basalts and a thick sand unit which overlies the siltstone (Plate II), it cannot be easily placed within a published stratigraphic system for the Snake River Plain. It is an important subsurface unit and one that is very thick (900 m+) in the logs from the Webber-State No. 1 well. The unit also contains several aquifers each about 10 to 20-m thick which were tested in the Webber-State Well. Lithologic descriptions in the Webber-State well call these units sands, whereas in the Highland Livestock and Land No. 1 well they are

described as very calcareous siltstone. Closer analysis of the geophysical logs is warranted to determine both the lithologic character and the aquifer properties because these beds contain water that is at least 70^{o}C at a depth of 1200 m. beneath the Nampa-Caldwell areas.

<u>Glenns Ferry Formation.</u> The upper 500 to 700 m of sediment in the Nampa-Caldwell area is correlated with the Glenns Ferry Formation of Malde et al. (1963) based upon a distinctive charge in the electrical log character from the siltstones and shales of the underlying Chalk Hills (?) to a 50 to 70 m thick distinctive gray sand unit (Plate 11). Reconnaisance of Glenns Ferry Formation in exposures in the foothills along the north margin of the Snake River Plain indicate that the basal unit is a coarse-to-medium-grained, moderately sorted, arkosic sand If this correlation is correct, these sands persist out under the plain and are an important aquifer beneath the Nampa-Caldwell area. The well logs indicate several thinner sand aquifers higher in the section, and three or four silt or clay units 30 to 80 m thick (Plate 11). Of particular interest is a shallow "blue clay" unit described in logs of water wells over much of the area. This clay has been used by John Anderson (Idaho Department of Water Resources) as a datum to detect faulting by correlating the numerous water-well driller's logs in the area.

Malde and Powers (1963) identify five major facies of the Glenns Ferry from detailed studies in the Hagerman area. The lacustrine facies consists dominantly of massive layers of tan silt with faint diffuse gray bedding and is the greatest in volume. The fluviatile facies is composed of thick evenly layered beds of drab, very pale brownish-gray sand and some silt. Some layers are cross bedded and ripple marked. Among the layers are thin beds of dark-olive gray clay and paper shale characteristic of the flood-plain facies. The flood-plain facies is mostly fine graded beds 0.3 to 1 m thick composed of calcareous pale-olive silt in the lower part and dark clay in the upper part. A facies of arkosic sands and fine granitic gravel is common as basal beds of the Glenns Ferry. The formation locally contains oolitic limy sands and algal limestones which were deposited around shoals or as a shoreline facies. East and west of the Nampa-Caldwell map area the unit is known to contain silicic volcanic ash layers, but none were found in the mapped area.

All lacustrine silts and clays exposed in the map area are mapped as Glenns Ferry Formation (Plate III), except the uppermost 30 meters exposed in the cliffs in the southwest corner of the Lake Lowell Quadrangle which are considered Bruneau lacustrine deposits. These Bruneau deposits overlie tilted Glenns Ferry silts and the Tuana Gravels. Massive fine sands and silts that underlie the Tenmile Gravels are also mapped as Glenns Ferry. Several exposures of gray laminated silts along the north side of the Boise River Valley, east of Middleton are also mapped as the Glenns Ferry Formation. Savage (1958 and 1961) mapped some of these lacustrine beds as facies of the younger "Nampa-Caldwell sediments," but I found no basis for placing them in a unit different and younger than the Glenns Ferry.

The best exposure of Glenns Ferry in the map area is in the southwest corner of the Lake Lowell Quadrangle where about 100 m is exposed. The upper 90 m are lacustrine facies that overlie 10 m+ of the fluviatile sandstone facies which outcrops as small cliffs of cross-bedded and ripplemarked, poorly sorted sandstone

The Glenns Ferry is an extensive unit in the Snake River Plain. Duration of deposition is thought to encompass the Pliocene-Pleistocene boundary. Evernden et al. (1964) give a K-Ar date for basalt in the lower part of the Glenns Ferry of 3.4±0.3 m.y. The meager chronology for this unit is briefly reviewed by Birkland et al. (1971) and is currently being restudied by Neville et.al(.1977) using paleomagnetic techniques.

Tuana Gravels. Well sorted pebble and cobble gravels Qg and coarse sand are exposed along the walls of the Snake River Canyon (Deadhorse Canyon in the SW corner of the Lake Lowell Quadrangle). The Tuana Gravels contain a few clasts of orange quartzite indicating a Snake River drainage provenance and distinguishing them from the Tenmile Gravels. At this locality Tuana grave dip 5 to 10^{o} north and mark an angular unconformity with the overlying, horizontal, Bruneau lake beds. Thickness of gravel is 0-50 feet.

Ten Mile Gravels. Most of the rolling hills and northwest Qtg trending ridges in the area are capped by 10 to 30 m of cobble and pebble gravels which Savage (1958) named the Tenmile Gravels. The unit is comprised of massive, locally imbricated gravel beds 0.5 to 2 m thick interbedded with coarse, cross-bedded arkosic sands 0.1 to 0.5 m thick. The clasts are almost entirely granitic rocks andfelsic porphyries derived from terrain of the Idaho Batholith north of the plain. Basalt clasts are very rare and make up less than 0.5%. The gravels are indistinguishable from gravels of the present Boise River and other gravels mapped as the sediments on the Deer Flat Surface and the gravels on the Whitney Terrace.

The Tenmile gravels thicken to the northeast and can be traced to a massive fan deposit of gravels up to 150 m thick heading in the mountains just west of Boise and south of the Lucky Peak reservoir. The train of gravels is identified as remnants along the hills marginal to the present Boise River and possibly the lower Payette River Valley from Lucky Peak Reservoir area to the Oregon border by Nyassa, a distance of 75 km. (Savage, 1958) and represents gravel sheet of considerable dimension.

The stratigraphic relation of the Tenmile gravel to other Plio-Pleistocene units in the Snake River Plain is uncertain. It clearly overlies the Glenns Ferry Formation, but it has not been clearly related to the Tuana Gravels and the Bruneau Formation. These latter units are confined to the south margin of the plain near the course of the present Snake River (Fig. XX). Between the areas of deposition of the Bruneau Formation and the Tenmile Gravels is a broad high area of Snake River Basalts (Figure XXX) which cover areas in which the Tenmile gravels might be stratigraphically related to deposits of Bruneau age. The Tenmile gravels contain so few basaltic clasts, and in places are overlain by Snake River Basalts, that they clearly must be older than the Snake River group and probably older tha much or all of the Bruneau Formation. The highlands which isolated the ancestral Boise River from the Snake River Drainage no longer eixsts. Malde (1978, oral communication) indicates a highland must have existed in the plain north of the Snake River in order to confine the lacustrine deposits of the Bruneau and explain lacustrine features and deposits up to an elevation of 968 m (3180 ft) along the south side of the plain (Malde, 1965). He proposes that the highland has since been removed by erosion.

Malde (quoted in Savage, 1958, p. 38) at one time thought the Tenmile gravels were possibly of the same age as more easterly deposits of Pasadena Valley and the Sugar Bowl gravels of Malde et al. (1963). The Sugar Bowl gravels by the town of Glenns Ferry are relatively fresh gravels whereas the Tenmile Gravel surface has a well-developed soil profile and a caliche layer and must be substantially older. Since the Tenmile gravels are overlain by the Snake River basalts, where they are associated, they are probably considerably older than the basalts and may have been deposited shortly after the Glenns Ferry time, or in the early Pleistocene.

Qlb
Qbb
Qbt

<u>Bruneau Formation.</u> Deposits of the Bruneau formation are quite limited in the map area and are exposed only on the southwest corner of the Lake Lowell Quadrangle. The horizontal tan-and-white lacustrine silts and fine sands of the Bruneau Formation unconformably overlie tilted Tuana Gravels at this locality. At the east edge of the map another exposure of Bruneau Formation is comprised of basaltic tuff and partly palagonized basaltic ash mixed with brown lacustrine silt. Total thickness of exposed Bruneau is about 30 m in the map area. Exposures lie between 2720 and 2810 ft (829-856 m). Since the Bruneau Formation is confined to the south margin of the Plain (Fig. XX) it is not likely to occur in the subsurface near Nampa or Caldwell. Eroded basalt vents of Bruneau age occur south of Lake Lowell. Basalt has intruded and locally arched the Glenns Ferry at several places within the Snake River Valley. Bruneau flows and cinders may be encountered down to depths of 50 to 100 m in the southern part of the mapped area.

The Bruneau Formation is 200 m thick in the Bruneau-Grandview area. The lacustrine rocks are viewed by Malde (1965) to be the result of lava dams within the Snake River Canyon. Numerous such dam must have existed (Fig. XX). According to Malde's concept the lacustrine Bruneau was entirely the result of lava damming in the Snake River Valley during a time of basaltic eruptions.

Age of the Bruneau Formation is briefly reviewed by Birkeland et. al.(1971). All basalt in the formation is of reversed magnetic polarity which implies an age older than 700,000 yrs, and most likely within the Matuyama reversed epoch spanning the period 0.7 to 2.4 million yrs.

Sediments of the Deer Flat Surface. The higher upland surface both north and south of the Boise River is underlain by at least 30m (100 ft) of unconsolidated fluvial sand and gravel. The sands are mostly coarse, arkosic, and crossbedded. The gravels are typically in beds 0.5 to 2 m thick and are composed of rounded clasts of intrusives derived from the Boise River drainage. The gravels are indistinguishable from the Tenmile Gravels. The unit is identified by its topographic poistion on a surface that is about 200 ft (60m) above the Boise River. The surface rises generally from a 2500 ft (760 m) on the west side of the map(Plate) to 2700 ft (823m) elevation in the northeast corner of the Middleton 7½-minute quadrangle. A good exposure of this unit is located in a gravel pit in the SW¼, Sec. 3, T.4N.,R.3W., 3 km north of Caldwell. No extensive exposures of this unit are known south of the Boise River. Priest et. al.(1972) classify soils upon this surface in the Scism or the Power-Durham series characterized by a moderately well-cemented caliche horizon 0.5 to 1.2 m deep.

Qdf
Qdf₁

The Indian Creek Basalt flows erupted onto surfaces of the Deer Flat Sediments, and appear in the driller's logs to be interbedded with this unit. The unit is probably middle Pleistocene in age.

Indian Creek Basalt Flows. Basalt which outcrops in Sec. 13, T3N.,R.1W. by the Nampa State School and in north Caldwell along the Boise River is the same flow unit. This flow is named the Indian Creek Basalt for it extends as a continuous flow about 0.7 km wide to Caldwell and parallels the course of Indian Creek. Subcrop of this flow has been mapped from the numerous driller's logs in the area. The flow is a gray, titano-augite-plagioclase-olivine basalt, and is typical of basalts of the Snake River Group. The gray color results from an abundance of small lath shaped plagioclase crystals. Qib

One or more deeper flows are identified from the the water-well driller's logs at depths of 50 to 100 ft (15 to 30m). This deeper flow underlies much of the city of Nampa, but the shallow flow lies mostly to the north of Nampa. Subcrops of the flows are shown with dotted lines. Both flows probably erupted onto an aggrading surface of sediment and can be considered as interbedded with the fluvial sediments of the Deer Flat Surface. Paleomagnetism of samples from three localities was measured with a field fluxgate magnetometer. Declination was consistantly east-northeast, and inclination was much to shallow to clearly identify the direction of paleomagnetism as reversed or normal.The cause of this anomalous magnetization is unknown. Because of the association of the flows with the Sediment of Deer Flat Surface, and the presence of an indurated caliche, the age of these basalts is probably middle Pleistocene.

Whitney Terrace Deposits . Alluvium of the Whitney Terrace (Nace et. al.,1957) consists of rounded cobble and pebble gravels, arkosic sands, and minor silts. The unit is identified by the relatively flat terrace surface 10 to 20 m above the present Boise River flood plain. Soils developed upon the terrace gravles have a well developed profile with a brown silty clay loam "B" horizon composed of up to 0.9 m of calcareous nodules extending to a depth of up to 1.3 m. These soils are assigned to the Power and Greenleaf series by Priest et. al.(1972). Profile development on this surface suggests a pre-Wisconsin age for the Whitney Terrace Deposits, or an age of 100,000 yrs. or more. Qtw

Quaternary Alluvium and Fan Deposits. Recent fluvial deposits cover the modern flood plains of the Boise River and Indian Creek. The Boise River flood plain is about 5km wide in the map area. In the Middleton Quadradnge, ephemeral tributaries have formed small alluvial fans that extend into the Qal Qaf

Boise River flood plain.

STRUCTURE

Faulting

A number of faults were located in recent excavations. Where the fault plane is accurately located and exposed, the attitude is shown on the map. Because exposed fault planes generally have a northwest-southeast orientation, the similarly trending linear ridges and swales are interpreted as eroded fault line scarps, but the questionable fault symbol denotes that both their location and existance is uncertain. These features are probably preserved because by a cap of faulted and caliche-cemented gravels.

The "North Caldwell Fault" is the only well documented fault nearby or within the city limits. The fault plane is well exposed in excavations behind the frozen food plant at N. Illinois Ave. and Plymouth Street. Amount and sense of offset on the fault cannot be determined from the exposure, but minimum offset must be at least 2m. The fault trends in west-northwest direction and is nearly vertical. The offset sediments are the middle(?) Pleistocene sediments of the Deer Flat surface (Qdf). The overlying Basalt of Indian Creek (Qib) may be offset, but one cannot be certain without excavating a large area along the nearby ditch. A low , subdued escarpment on the lava flow suggests a minor amount of offset, but area east of the exposure has been modified by development.

Folding and broad warping

Most exposures of the Tenmile gravels and the underlying Glenns Ferry Formation appear to be flat lying except in the vicinity of faults. Exception to this generalization is the southeast corner of the Lake Lowell Quadrangle where the strata dip about 7^{o} to the northeast. Exposures south of here along the Snake River, and on the north flank of the Owyhee Mountains have a similar attitude. This implies that a monoclinal or synclinal axis lies nearby or north of the Lake Lake Lowell area. If the Glenns Ferry Formation and underlying units are broadly tilted in this manner, then the attitude of the aquifers, as well as faulting, may influence the upward migration of geothermal waters. In other words -- warm waters may migrate up dip and appear nearer the surface in the Lake Lowell area.

GEOTHERMAL AQUIFERS

Plate II shows that a sand aquifer at the base of the Glenns Ferry can be widely correlated over the area. This sand unit lies at depths of about 500m over much of the area. Temperatures from the well data (Plate II and Fig. 4) suggests waters with minimum temperatures of 40^{o} to 50^{o} C can be expected from this unit. Other aquifers may be present within the basalt section on the structural high (Fig.1) or also in the basins on the flanks of the high such as the sands at the bottom 20m of the Webber-State No. 1 well (Plate II).

It is recommended that existing geophysical logs be carefully analyzed to determine which of these aquifers have sufficient permeability to yield economic amounts of geothermal waters.

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ADDENDUM

Kittleman, L. R., Green, A. R., Hagood , A.R., Johnson, A.M., McMurray, J. M., Russell, R. G., and Weeden, D.A., 1965, Cenozoic stratigraphy of the Owyhee region, southeastern Oregon: Bull. No 1, Museum of Natural History, University of Oregon, Eugene, 45 p.

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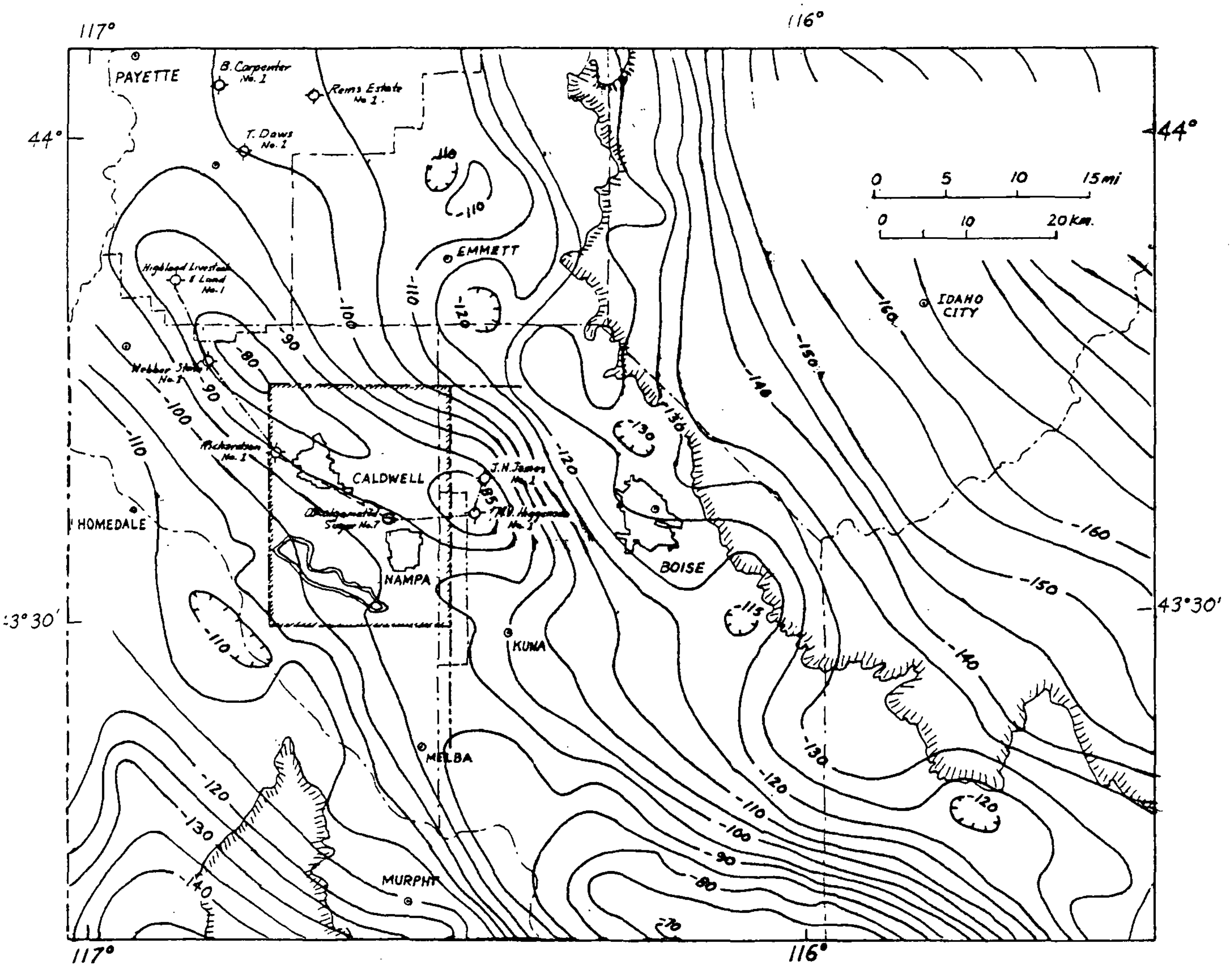

Figure 1. Generalized Gravity Map of the western Snake River Plain (from Maybe, 1976) and location of deep wells.

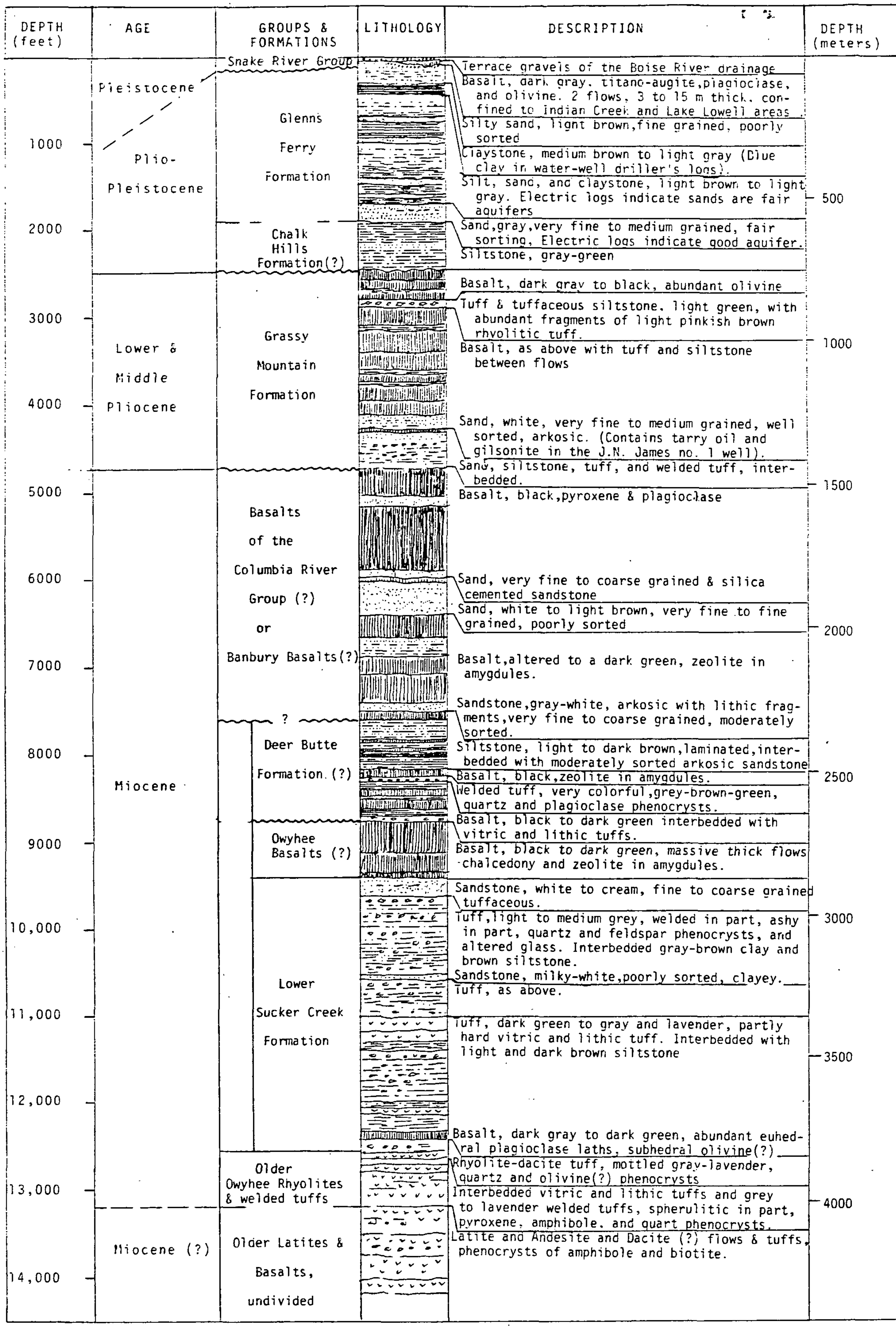

FIGURE 2. Stratigraphy for the Nampa-Caldwell area based largely upon the lithologic log (J.E. Hiner, 1976) and geophysical logs from the Standard Oil of California - M.T. Halbouty Co. exploratory well: J.N. James no. 1 near Meridian, Idaho. Stratigraphic units are defined by Kittleman et. al.(1965) and Malde et. al. (1963). A slightly different interpretation of this lithology can be found in Warner(1977). Difficulties in applying existing stratigraphic nomenclature to these subsurface units are discussed in the text of this report.

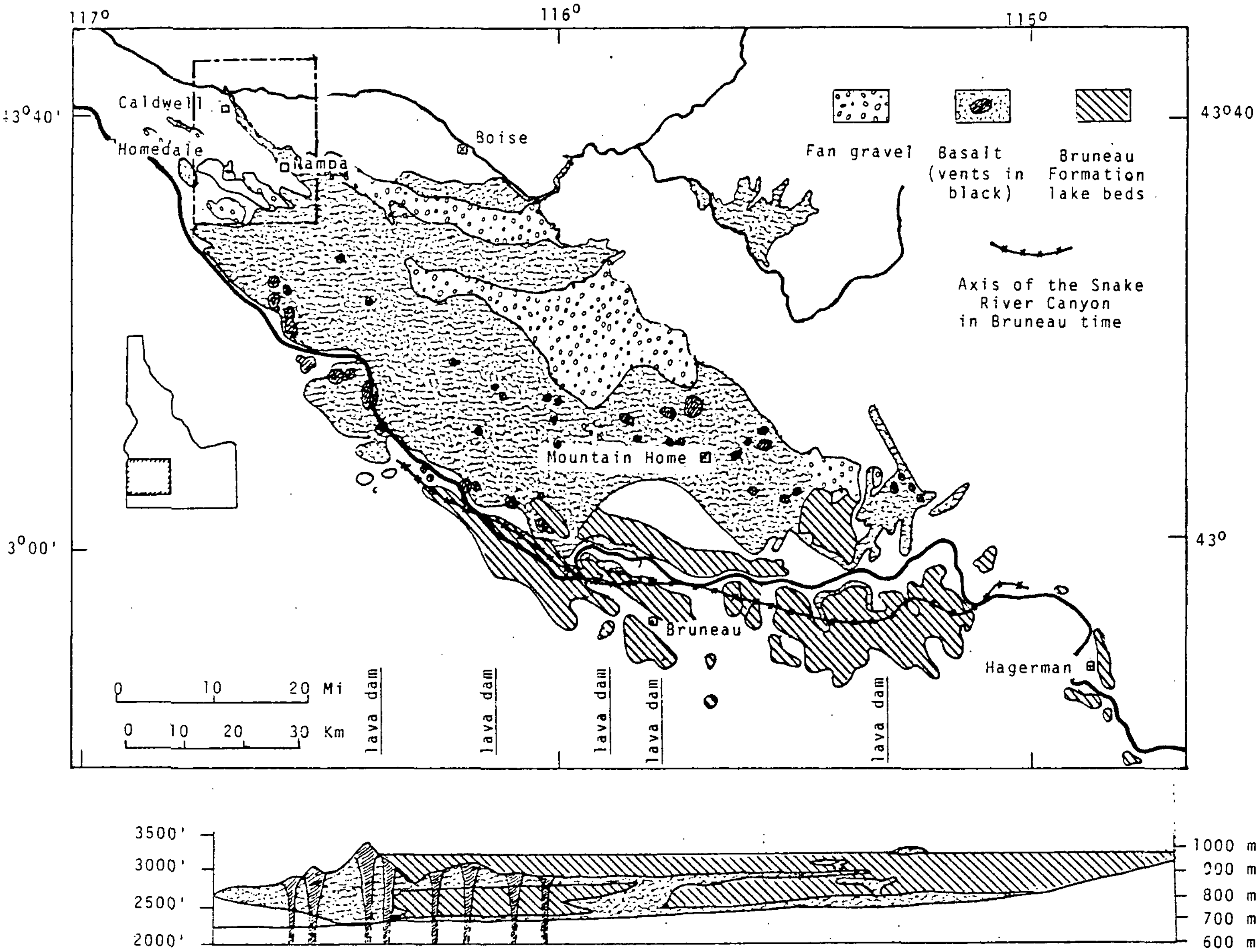

Figure 3. Map of the Bruneau Formation lacustrine deposits and related rocks (After Malde, H.E., 1965)

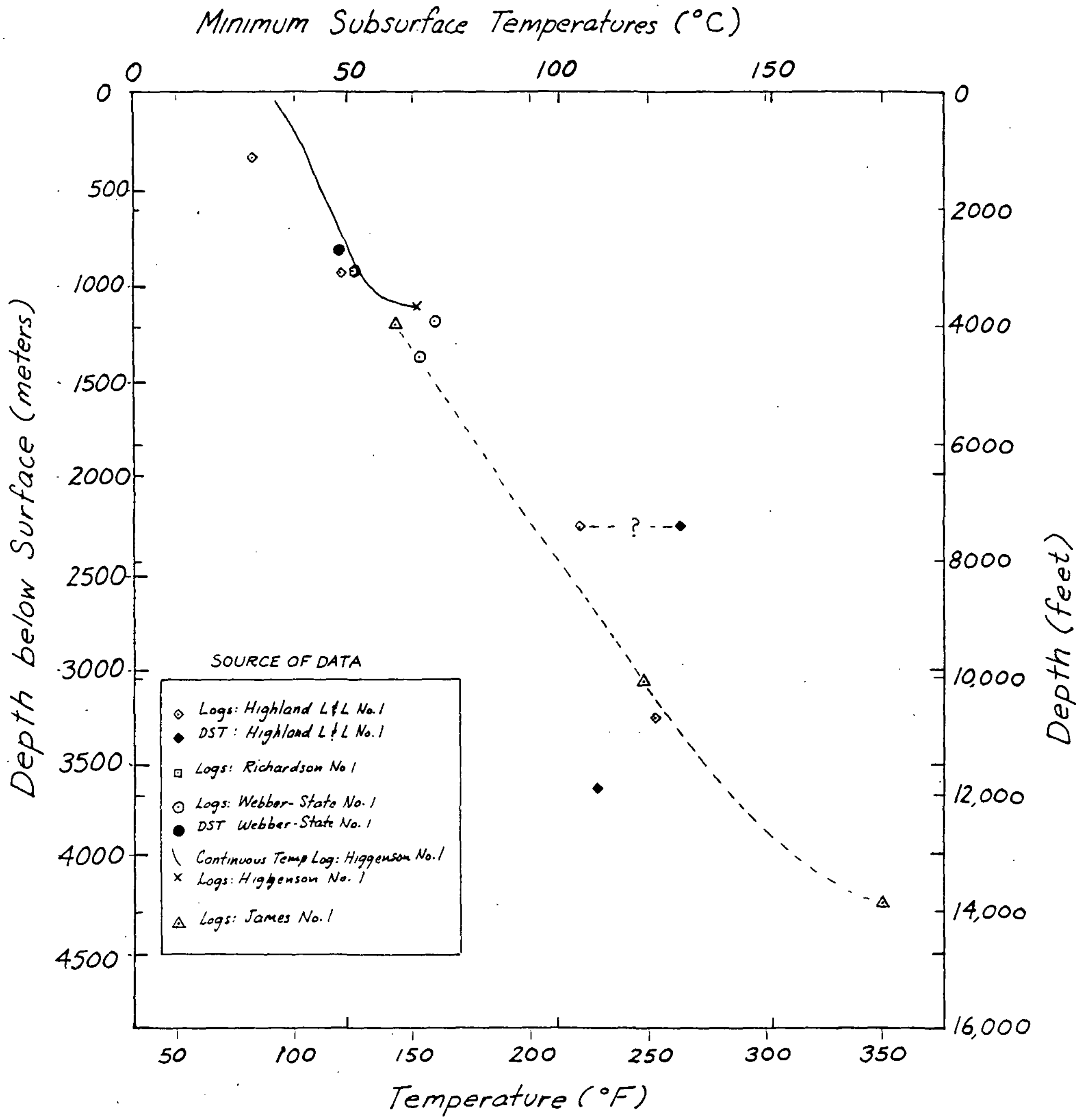

Figure 4. Plot of subsurface temperature data from wells versus depth. These are considered minimum temperatures because of the cooling effect of circulating well fluid.