U.S. DEPARTMENT OF THE INTERIOR

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PRELIMINARY GEOLOGIC MAP OF NAVAJO LAKE QUADRANGLE, KANE AND IRON COUNTIES, UTAH

by

David W. Moore[1] and L. David Nealey[1]

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This map is preliminary and has not been edited or reviewed for conformity with U.S. Geological Survey editorial standards and stratigraphic nomenclature.

[1]USGS, Federal Center, Denver, Colorado

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DESCRIPTION OF MAP UNITS

Note: Most sedimentary bedrock in the map area is concealed by colluvium (Qc). The main purpose of the map is to show the distribution and structure of the bedrock. Thus, only a fraction of the colluvium was mapped where it is thickest. Colors of rocks, soils, alluvium, and weathering products were selected using a Munsell Soil Color chart and the Rock-Color Chart (Goddard and others, 1948). Sedimentary rock names follow the field classification of C. M. Gilbert (as illustrated in Williams and others, 1958, p. 270)

Qal **Alluvium (Holocene)**--Low-level deposits on floodplains and in channels that consist of gravel and sand, silt, and clay mixed in varying proportions. At edges of floodplain, grades into colluvium (Qc) and fan alluvium (Qaf1). Midway Valley floodplain deposits are dark brown (7.5YR 3/2) to strong brown (7.5YR 4/6); thick to thin-bedded; lenses of fine pebbles. The channel contains basalt and limestone gravel (2-50 cm in diameter) in a matrix of coarse sand, with subordinate light-gray (N7) ash-flow tuff of Isom Formation of latest Oligocene age (1-10 percent), white chalcedony (1-2 percent), and well rounded black chert pebbles (2-3 percent). The channel in Deer Valley is small or absent; floodplain alluvium is silty clay to clayey silt, yellowish red (5YR 5/8), slightly sandy, laminated to massive, and contains lenses, 2-40 cm thick, of angular limestone pebbles and some cobbles. Floodplain alluvium of Mill Creek (southwest quarter of quadrangle) is medium gray (N5), sandy and clayey silt to silty clay; thin interbeds of pebbles (limestone, basalt and sandstone); is terraced behind old beaver dams in places. Base covered; estimated thickness 2-5 m

Qaf1 **Alluvial-fan deposits (Holocene)**--Fans around Navajo Lake: upper fan, chiefly clast-supported coarse gravel of limestone and minor sandstone and conglomerate containing some sandy matrix; middle to lower fan, pebbly sand to sandy pebble gravel, angular fine limestone pebbles, scarce small cobbles (8 cm in diameter); reddish yellow (5YR 6/6), poorly sorted, loamy quartz fine sand; distal fan is silty, slightly pebbly and clayey, very fine to coarse quartz and limestone sand, crudely stratified. Some hard layers 10-20 cm thick are cemented by calcium carbonate. East of dam, alluvium interfingers and grades to lake sediment (Qla) toward axis of valley; along shore it interfingers and grades to lake gravel (Qlg). At west end of Midway Valley, scarce ash-flow tuff (Isom Formation) gravel 20-80 cm in diameter occurs in moderate brown (5YR 4/4), silty fine sand matrix. On and south of plateau escarpment (Pink Cliffs), alluvium is dark-yellowish-brown (10YR 4/4) sand, silt, poorly to moderately well-sorted sand, pebbly sand, and silt, intermixed and interbedded. Thickness estimated to be 5-7 m at mid-fan

Qat1 **Alluvial-terrace deposits (Holocene)**--In Midway Valley, sandy, poorly sorted, resistant gravel of basalt, ash-flow tuff of the Isom Formation, chalcedony, and sparse, round, chert and quartzite pebbles. Top of terrace is 1-2 m above stream channel. On Mill Creek, silty, very fine, quartz sand, and heterogeneous gravel composed of limestone, calcite-cemented sandstone, and minor basalt (10 percent); silty sand is dark yellowish brown (10YR 4/4) and friable. Estimated thickness 1 m

Qac **Sheetwash alluvium (Holocene)**--Clay, silt, very fine sand, and fine gravel, intermixed and interbedded. Grayish-orange pink (10R 8/2) subangular to subround limestone pieces 2 mm-15 cm long in a sandy, silty clay to clayey silt matrix; dark brown (7.5YR 3/4) and strong brown (7.5YR 5/6). Upper 2 m is chiefly silt that contains minor gravel. Laminations 1-3 mm and bedding 10-20 cm thick. Accumulations in topographic lows on Markagunt plateau upland developed on Claron Formation. Base covered; estimated thickness 2-5 m

Qc **Limestone and sandstone gravel colluvium (Holocene)**--Gravel and sediment derived from weathered rock. Light brown (5YR 6/4, dry), strong brown (7.5YR 5/6, moist), moderate reddish orange (10R 6/6, dry), and reddish brown (5YR 5/4, moist). Chiefly limestone and sandstone clasts that range from granules to small boulders; exceptional clasts are as large as 5-7 m across. Locally, subordinate volcanic tuff and (or) basalt. Widespread; mapped selectively where deposits are thickest. Matrix is unsorted, rarely stratified mixed grus, silty fine sand, clayey silt, and clay that has crept or washed downslope. Thickness of mapped colluvium estimated 4-17 m

Qcv **Volcanic gravel colluvium (Holocene)**--Gravel, grus, lithic sand, silt, and clay, intermixed. On the Markagunt Plateau in the north part of the quadrangle, it mantles hillslopes formed on the thickest breccia of Isom Formation (QTbx). Matrix is grus, lithic sand, and silt. Composition reflects that of the nearest rock exposed upslope: calc-alkalic ash-flow tuff porphyry of Isom breccia (QTbx) and basaltic lava flows (Qb series). In places, tuff and basalt are mixed. Some basalt clasts are blocky with angular to subrounded edges where they were recently derived from young basalt flows. Spheroidal weathering has occurred on clasts derived from older basalt flows and from Isom breccia. Base covered, estimated thickness 2-3 m, but as much as 4 m at foot of the relatively steep hillslopes

Qmt1 **Talus (Holocene)**--Loose, angular, rock fragments deposited on slopes by rockfalls; steeply sloping; most fragments range from silt size to blocks 1-5 m across; finer material is light brown (5YR 6/4). Limestone, sandstone, and subordinate quartz-pebble conglomerate; a few blocks as large as 8-10 m across rest at foot of some steep hillslopes. Downslope, unit grades to colluvium. Thickness about 2-15 m

Qla **Lacustrine and alluvial deposits, (Holocene)**--Sediment washed from adjacent hillslopes into a natural, intermittent, lake basin upstream of a lava flow (Qbf1). The natural lake predates the man-made Navajo Lake shown on the map. Deposit is generally silty, very fine, quartz sand, light brown (5YR 6/4 to 5YR 6/6) and moderate yellowish-brown (10YR 5/4); lowest layer exposed in stream cut is 50 cm thick and is strong brown (7.5YR 4/6), slightly sandy, and silty clay; it is overlain by 30-40 cm of light-gray (10YR 7/2), silty clay to clayey silt. Scattered subangular limestone pebbles in center of lake basin, grading to gravel (Qlg) near shore. Stratified and interbedded with very fine sandy silt, clayey silt, and silty clay. Common fragile, high-spired, white snail shells 0.5 cm diameter. Deposits alternately subaerially exposed and flooded. Base of deposit generally not exposed, but basalt boulders were seen under the unit in the sinkholes (called Navajo Sinks by Wilson and Thomas, 1964) about 400 m east of the man-made dam. The sediment-basalt boulder contact may be base of unit; estimated thickness 1.5-5 m

Qlg **Lacustrine gravel (Holocene)**--Limestone pebble gravel, very pale orange (10YR 8/2); sandy. Grades into lacustrine and alluvial deposits (Qla). Estimated thickness 0.5-2 m

Qo **Peat (Holocene)**--Brownish black (5YR 2/1) watersaturated, partly decomposed, plant material and minor clay and silt. Dense organic mat of grass roots, moss, herbaceous annuals; spongy, soft surface; scarce, light-gray chitinous, bivalve shells 3-5 mm across. Forms level to 0.5^{o} slope on valley floor west of Navajo Lake; also in sinkholes on limestone plateau. Estimated thickness 0.5 to several meters

Qes **Eolian sand (Holocene)**--Clayey calcareous sand; grayish-orange (10YR 7/4) to very pale yellowish brown (10YR 7/2); accumulations of loose, clastic grains of sedimentary rock on the rim of Cedar Breaks National Monument (northwest part of quadrangle), carried by winds that ascend west-facing cliffs. Subspherical medium sand-sized aggregates of weathered limestone and calcareous mudstone grains, clay-, silt-, and subordinate very fine sand-size quartz grains. Soft when dry; slightly plastic when wet (consistency terms from Soil Survey Staff, 1951, p. 232). Contains 5-10 percent angular wind-deposited limestone pieces 2-15 mm long. Active slumping indicated by tilted trees on hummocky hillslopes of deposit. Unit buries a 1-m-thick layer of colluvial lag gravel and breccia (QTbx) that mantles the white unit of Claron Formation (Tcw). 1.5-6 m thick

Qms **Landslide deposits (Holocene and late Pleistocene?)**--Masses of gravitationally displaced colluvium, soil, and rock, broken and disaggregated. Mostly slumps, some rotational slides contain large, relatively coherent blocks of strata. Estimated thickness 2-6 m; largest slides may be as thick as 15 m

Qaf2 **Older alluvial-fan deposits (late to middle Pleistocene?)**--Poorly sorted, crudely stratified gravel and matrix; particle size ranges from clay to boulders. Chiefly limestone and sandstone gravel in light brown (5YR 5/6), slightly clayey, sand and silt matrix, firmly cemented; lenses of stratified, sorted, fine quartz sand 1-2 m thick. Visually estimated composition of clasts is as follows: subrounded to rounded clasts of gray, white, and pink limestone of Claron Formation (65-70 percent); white pebbles and cobbles of well-rounded, tan and white metaquartzite (20 percent): light brown, arkosic, subarkosic, and slightly feldspathic quartzose sandstone and dark-brown, limonitic (oxidized pyritic) concretions (10 percent); and olivine basalt (1 percent). A few clasts of mudstone and ash-flow tuff are present in places. Occurs downslope from Pink Cliffs between 2,560 and 2,804 m (8,400 and 9,200 ft) elevation. Forms elongate erosional remnants that cap interfluves on relatively soft Cretaceous strata and that occur at a topographic level 4-10 m higher than younger fans (Qaf1); forms sloping surfaces at head of drainages and base of cliffs. Thickness 2-7 m

Qat2 **Older alluvial-terrace deposits (late to middle Pleistocene?)**--Poorly sorted gravel, grus, and sand. Composition variable; in places predominantly vesicular and dense basalt boulders (as large as 2 m across) and 1-3 percent clasts of ash-flow tuff porphyry (Isom Formation); elsewhere, clasts of ash-flow tuff are prevalent. Both clast- and matrix-supported. Spheroidal weathering and stream transport has rounded clasts. Deposits mantle terraces adjacent to and 12-16 m higher than main ephemeral streams. Along Midway and Long Valley Creeks, deposits mantle small, discontinuous, terraces. Active downslope creep apparently has imparted a slightly domal form to these terraces. Thickness of deposits 2-4 m

Qmt2 **Older talus and colluvium (late to middle Pleistocene?)**--Composition like younger talus (Qmt1) except deposits form degraded erosional remnants that armor small hilltops downslope from Pink Cliffs. Estimated thickness 2-7 m

Qa **Older alluvium (early to middle Pleistocene?)**--Poorly sorted material ranging from silt to boulders composed of limestone, sandstone, quartzite, scarce chert, and basalt; round to subround clasts. Two isolated deposits form sloping, rounded, resistant armor on narrow interfluves of relatively soft Wahweap Sandstone west of Mill Creek at southwest edge of quadrangle. Original landform eradicated by gravity and erosion; probably old stream terrace or fan alluvium. Estimated thickness 2-5 m

Qbf_1 Qbv_1 **Olivine-plagioclase mafic volcanic rock (Quaternary)**--Blocky lava flows of fine- to medium- grained porphyritic basalt, basaltic andesite, and some trachy-andesite (fig.1) containing phenocrysts of olivine and plagioclase; having conspicuous olivine+plagioclase+ clinopyroxene glomerocrysts; phenocrysts and glomerocrysts set in a matrix of olivine, plagioclase, clinopyroxene, Fe-Ti oxides, and glass. Sparse to common olivine phenocrysts attain maximum dimensions of 2 mm. Olivine frequently encloses brown Cr-Al spinel inclusions. Sparse to common plagioclase phenocrysts attain maximum lengths of 2 mm and average 1 mm in length. Lava flows (Qbf_1) were erupted from small central vent areas (Qbv_1). Flows locally contain vesicle pipes. Compositions represented by samples NNL-3, NNL-17 and NNL-16 in table 1

Qbf_2 Qbd_2 **Clinopyroxene-olivine basalt (Quaternary)**--Mesa capping lava flow and dike of medium-grained porphyritic basalt, containing phenocrysts of clinopyroxene, olivine, and plagioclase; conspicuous clinopyroxene+olivine glomerocrysts as large as 7 mm in diameter; phenocrysts and glomerocrysts in a matrix of clinopyroxene, olivine, plagioclase, Fe-Ti oxides, and glass. Common clinopyroxene phenocrysts attain maximum dimensions of 3 mm and average 1 mm. Common olivine phenocrysts attain maximum size of 3 mm and average 2 mm. Clinopyroxene shows variety of hourglass, concentric, and other complex zoning patterns. Lava flow (Qbf_2); dike (Qbd_2). Flow extends into Straight Canyon quadrangle. Composition represented by samples NNL-28 in table 1

Qbf_3 Qbc_3 **Olivine-clinopyroxene-plagioclase basalt (Quaternary)**--Blocky and cinder-covered lava flows and cinders of medium-grained porphyritic basalt containing phenocrysts of olivine, clinopyroxene, and sparse plagioclase; common glomerocrysts of olivine+plagioclase+ clinopyroxene, maximum dimensions of 4.5 cm, average size less than 1 cm in diameter; matrix of olivine, clinopyroxene, plagioclase, Fe-Ti oxides, and glass. Common olivine phenocrysts attain maximum dimensions of 4 mm and average 1 mm in dimension. Olivine commonly encloses brown Cr-Al spinel inclusions. Common plagioclase phenocrysts attain maximum dimensions of 1 cm but average 0.5 to 1 mm. Sparse clinopyroxene phenocrysts as large as 2 mm in diameter. Lava flows (Qbf_3) were erupted from cinder cones (Qbc_3). Compositions represented by samples NNL-5, NNL-6, NNL-12, NNL-15, NNL-25, and NNL-26 in table 1

Qbf_4 **Olivine-plagioclase trachybasalt (Quaternary)**--Lava flow of fine-grained porphyritic trachybasalt, containing phenocrysts of olivine, plagioclase, and clinopyroxene. Olivine and plagioclase phenocrysts are common and average about 1 mm in maximum dimension. Flow underlies younger, olivine-plagioclase, mafic, volcanic rocks (Qbf_1) and is distinguished from younger mafic volcanic rocks by a lighter color caused by more abundant plagioclase crystals. Flow erupted from an unknown source. Composition represented by sample NNL-13 in table 1

QTrg **Gravelly decomposition residuum and colluvium (Quaternary and Late Tertiary)**--Sandy and silty heterogeneous unsorted gravel ranging in size from small pebbles to boulders as large as 2 m across. Surface lag of gravel, grus, sand, and silt of ash-flow tuff, basalt, and 3-5 percent smooth, well-rounded, fine-to medium-sized pebbles of grayish-black (N2) chert and pale-brown (5YR 5/2), dark-reddish-brown (10R 3/4) quartzite; the pebbles were derived from pebble conglomerate in white unit of Claron Formation (Tcw) or lower part of Brian Head Formation of Gregory (1944). Texture and composition of this unit suggests that a mantle of breccia made of ash-flow tuff (Isom Formation) was covered by a basalt flow, followed by a long period of weathering. Unit was produced by chemical decay and physical disintegration of boulders with no subsequent lateral transport except for downslope creep; forms unusually smooth, symmetrical, domal hills that have 1-2^{o} summit slopes and 2-4^{o} shoulder slopes. Characteristics of the Bt horizon (layer of translocated clay accumulation in surficial soil) suggest weathering during an extended period of time. The Bt horizon is 1-1.5 m thick, dark brown (7.5YR 3/4, wet), gravelly clay to clay loam, having strong, large blocky soil structure and thick clay films. Covering the Bt horizon is a surficial thin layer (A horizon) that is moderate yellowish brown (10YR 5/4), pebbly, slightly clayey silt to silty very fine sand. In sinkholes, dropped slightly below the unit, are spheroidally weathered basalt boulders, emplaced when the sinks collapsed under a pre-existing lava flow. Estimated thickness of deposit 0-3 m

QTbx **Breccia (Pleistocene and Late Tertiary)**--Surficial, unconsolidated resistant mantle of angular rock fragments chiefly derived from broken up 26-Ma-old sheet of ash-flow tuff of Isom Formation. Unit locally contains individual clasts or irregular masses of white to very pale brown tuffaceous sandstone, mudstone, limestone, pebbles of chert and quartzite, and variegated chalcedony. Particle size ranges from silt to blocks as large as 4 m in diameter. Forms boulder-strewn, hummocky terrain pockmarked with closed depressions. Excellent exposures at Blowhard Mountain reveal that the unit encloses scattered irregular masses of broken, disaggregated and intermixed white limestone, sandstone, mudstone, conglomerate, and chalcedony derived from lower Brian Head Formation, of Gregory (1944, p.591). The masses are 3-30 m across and the largest and lowest overlies alluvial boulder gravel 3-5 m thick in a paleovalley cut into the red unit of Claron Formation (Tcr). Brecciation of the sheet of late Oligocene (Fleck and others, 1975) ash-flow tuff (Isom Formation) resulted from repeated landsliding (Moore, 1992) in the underlying unit and (or) tectonically-induced large scale gravity sliding (Sable and Anderson, 1985, p. 263) associated with breakaway faulting of the uplifting Markagunt Plateau. Maximum exposed thickness of 40 m at Blowhard Mountain; elsewhere breccia is estimated to be about 2-10 m thick

Claron Formation (Upper Cretaceous?-Paleogene)--Varicolored lacustrine and fluvial sediments. Alternating beds of sandy limestone and calcareous sandstone with fewer beds of calcareous mudstone and conglomerate; mostly nonfossiliferous. Previously called Wasatch Formation (Richardson, 1909; Gregory and Moore, 1931) and Cedar Breaks Formation (Schneider, 1967). Forms escarpment 270-340 m high at edge of Markagunt Plateau, mostly covered by colluvium and forest, but spectacularly exposed as colorful beds of the "Pink Cliffs" at Cedar Breaks National Monument and Cascade Falls. Mapped as two lithostratigraphic units: an upper white unit and a lower red unit

Tcw **Upper white unit**--limestone, mudstone, and minor sandstone. Base of unit is at base of a conspicuous 12-m-high cliff of white (N9) and very pale orange (10YR 8/2) uniformly micritic to locally pelmicritic limestone (informally called the "lower white limestone" in the Cedar Breaks National Monument area). Very sparsely charophyte-bearing in places. Above basal limestone is a 94 m-thick slope-forming interval of interbedded mudstone and sandstone that are yellowish gray (5Y 8/1) and moderate yellowish brown (10YR 5/4). Sandstone is dark yellowish orange (10 YR 6/6) to light brown (5YR 6/4), crossbedded, fine- to medium-grained quartz, 20 percent black chert sand grains, and slightly feldspathic ("salt-and-pepper" sandstone); near the middle of the 94-m-thick interval is a laterally persistent 2-3 m thick interval containing lenses of chert pebble conglomerate; the chert pebbles are distinctive in that they are remarkably smooth, well-rounded, uniformly black, and abundant. Uppermost bed in white member is a 13-m-thick, cliff-forming, micritic limestone (the "upper white limestone"). Upper white limestone is pale yellowish gray (5Y 8/2) to very pale orange (10YR 8/2) that weathers white (N9) to pale yellowish gray 5Y 9/1); contains intraclasts (torn up and redeposited bodies of micrite), pellets, calcite spar-filled vugs, and networks of calcite veinlets; basal 1-1.5 m of upper white limestone contains a few discontinuous irregular zones of chalcedony replacing limestone. The "lower" and "upper" white limestones, unlike limestones in the red unit, are nearly devoid of quartz sand. White unit of Claron Formation is 108 m thick at Cedar Breaks National Monument

Tcr **Lower red unit**--Alternating beds of pale reddish- to pinkish-colored sandy limestone, calcite-cemented sandstone, calcareous mudstone, and minor conglomerate composed of pebbles. Limestone is varicolored, commonly moderate red (5R 5/4), moderate reddish orange (10R 6/6) and very pale orange (10 YR 8/2), with mottled colors of grayish-orange (10 YR 7/4), dark yellowish-orange (10 YR 6/6) and moderate-pink (5R 7/4); microcrystalline; argillaceous locally; generally sandy (2-20 percent quartz sand). Common calcite spar-filled vugs and thin branching veinlets of calcite spar, crystals 0.5-2 mm long; dissolution cavities and surficial sinkholes; stylolites; locally cavernous. Calcite spar- and micrite-filled vertical burrows 0.5-4 cm diameter and 10-50 cm long are abundant in some limestone beds; limestone contains uniformly dispersed fine quartz sand, typically about 2-20 percent, rarely to 50 percent. Limestone rarely contains scattered, very sparse, aquatic, small bivalves (pelecypods?, branchiopods?, ostracodes?) and planispiral-coiled shells of gastropods; most limestone beds are massive (1-2 m thick); in detail, limestone is relatively pure, structureless micrite that grades to micrite containing dispersed quartz sand and (or) micrite balls 0.2-2 cm in diameter having concentrically laminated, or "onion-like" structure (accretionary oncolites? or oolites?), and (or) pebble-sized intraclasts (Folk, 1959) and pellets, in places angular and chaotically juxtaposed, imparting a breccia-like appearance to the rock, suggesting penecontemporaneous erosion, mixing, and deposition (with little or no transport) of soft marly sediment in a moderately energetic aqueous environment or a post-deposition alteration that mimics such deposition; crystalline calcite that fills vugs and replaces shells is diagenetic, as is some matrix. How the micrite bodies and breccia-like sedimentary structures formed is uncertain; formation in fossil soil horizons has been suggested (Mullett and others, 1988). Interbedded throughout unit is sandstone and mudstone. Sandstone forms ledges and is varicolored, thick-bedded, calcite-cemented quartz arenite, crossbedded in places. Mudstone is silty, calcareous, contains calcareous nodules, and weathers to earthy, steep slopes between ledges of sandstone and limestone. Conglomerate crops out as lenticular intervals, 2-5 m thick, and interfingers with grayish-pink (5R 8/2) to medium gray (N5), firmly cemented, quartzose sandstone. The sandy quartzite-pebble conglomerate was seen at 9, 12, 42, and 63 m above base of red unit of Claron Formation. Conglomerate beds persist 100-300 m laterally before pinching out and apparently are fluvial point-bar and channel deposits. Base of red unit placed at bottom of the first limestone beds above the Upper Cretaceous mudstone and sandstone (Kaiparowits? Formation). The basal limestone beds form a conspicuous pale-reddish-brown cliff 19-23 m high that is unbroken around the south edge of the Markagunt Plateau. At base of cliff are shallow caves and rough, irregularly eroded rock columns, and a recessive bed from which springs (like Cascade Falls) issue in places. Lower contact is gradational to sharp. Maximum eroded thickness 228 m in southeast corner of quadrangle at Cascade Falls. Schneider (1967, p. 189) measured 298 m in thickness for this unit (section 2B of Cedar Breaks Formation) at Adams Barrier in Cedar Breaks National Monument (1 mi north of the Navajo Lake quadrangle).

Kk? **Kaiparowits? Formation (Upper Cretaceous)**--Sandstone and subordinate mudstone and conglomeratic sandstone. Extension of the Kaiparowits Formation from its type area in the Kaiparowits Plateau region (Gregory and Moore, 1931) is of interest in a regional stratigraphic study. Thus, this unit is described in detail. The upper 10-18 m of the formation is chiefly cherty, argillaceous, yellowish and orange-colored "dirty salt-and-pepper" sandstone, whereas the remainder of unit is predominately "clean" gray-colored quartz arenite sandstone containing subordinate interbeds of mudstone. The "dirty" sandstone crops out in a NW-SE direction, more or less continuously, as a cliff or series of ledges 1-2.5 m thick immediately under the basal limestone of the Claron Formation; the sandstone is pale yellowish orange (10YR 8/6), and pale yellowish brown (10YR 6/2), dark grayish orange (10YR 6/4), weathers grayish orange (10YR 7/4) and moderate yellowish-brown (10YR 5/4), is poorly to moderately sorted, subangular fine- to coarse-grained subfeldspathic lithic wacke to subfeldspathic lithic arenite (Williams and others, 1958, p. 292). Base of "dirty" sandstone is sharp and undulatory where exposed, as in Slide Hollow (1 km NW of Blowhard Mt.) where the lower 2 m of the sandstone are grayish orange pink (5YR 7/2), sandy, varicolored small pebble mudstone conglomerate; in other places base of "dirty" sandstone interfingers with well-sorted, crossbedded, slightly feldspathic quartz arenite and silty mudstone. The "dirty" sandstone contains 8-15 percent black chert grains; 20-25 percent light gray, white, and tan angular chert grains; and 10-30 percent varicolored silty and clayey microcrystalline calcite (micrite) and siltstone sand grains, pellets, granules, small pebbles, and irregular bodies 0.5-8 cm across, whose prevalent colors are very pale orange (10YR 8/2), yellowish gray (5Y 8/1), and moderate orangish pink (5YR 8/4); accessory components in the sandstone include weathered feldspar grains (as much as 20 percent locally) and trace of greenish-gray mica; matrix is silty, argillaceous calcite that is about 4-12 percent of rock volume. Medium- to thick-bedded; uneven planar bedding and sets of small- to medium-scale crossbeds, 0.3-1 m thick, 1 cm-thick sets of tabular ripple crosslaminae that pinch out laterally; "dirty" sandstone contains calcite spar-filled vugs, robust, attached pelecypod shells (heart-shaped and as large as 9 cm) are common, fossil wood and a single vertebrate bone (15 cm long) were seen; limonitic replacement of organic fibrous material (bone? plant material?) is common. In contrast, sandstone elsewhere in the unit below the upper "dirty" sandstone is predominately very light gray (N8) to pale yellowish gray (5Y 8/2), very friable, well-sorted, fine- to medium-grained quartz arenite; lower part of unit is mostly covered and contains interfingering beds of Wahweap-like sandstone and thus appears to grade into the Wahweap Sandstone. The lower part of unit becomes a thick continuous sequence of quartz arenite from the southeast corner of quadrangle (at Cascade Falls) toward the northwest. In the northwest corner, the lower sandy part is a light gray where dry (N7) and dark gray where wet (N3), friable, water-bearing, crossbedded quartz arenite. Correlation of the unit to the Kaiparowits Formation of Gregory and Moore (1931) in the Kaiparowits Plateau region is open to question because in the Navajo Lake quadrangle the unit is very thin compared to the 600 m thickness of the formation in the type area; further, lack of definitive fossils precludes biostratigraphic corroboration. Thus, tentative correlation is based on stratigraphic position and subjective observations of lithology. However the bedding and lithology of both units are similar. Base of unit arbitrarily placed approximately in middle of interval where character of rocks becomes decidedly typical of underlying Wahweap Sandstone. Unit approximately 60 m thick

Kw **Wahweap Sandstone (Upper Cretaceous)**--Interbedded varicolored mudstone, sandstone, and lesser siltstone. Chiefly mudstone that is brownish gray (5YR 4/1), light olive brown (5Y 5/6), and moderate reddish brown (10R 4/6); weathers pale red (5R 6/2) and other mottled colors; silty to very fine grained quartz sand 30-40 percent; scarce pure clay. Interbedded clayey sandstone, grayish orange (10 YR 7/4) to dark yellowish orange (10YR 6/6), lenticular beds 1-2.5 m thick, crossbedded, and soft to friable. Ratio of mudstone to sandstone ranges from 2:1 to 4:1 in exposures along Utah Highway 14, 1-2 km west of quadrangle. Leaf impressions common in sandstone. In the southeast corner of the quadrangle 12 m of friable, water-bearing, dark gray (N3, wet) to olive black (5Y 2/1, wet) silty, slightly clayey fine-grained quartz arenite sandstone is exposed in a streamcut where all surrounding bedrock is covered. The top of this exposure is 101 m below the base of the Claron Formation. This, together with observations in cuts along Utah Highway 14 at the west edge of the quadrangle and in the adjoining Webster Flat quadrangle, is the basis for concluding that the upper part (one third?) of the Wahweap contains more sandstone than the lower two-thirds, which is predominantly mudstone. The sandstone is a clean, well-sorted, aquifer; it contains thin layers of carbonized fossil wood and spherical, pyrite-cemented, quartz-sand concretions, which are calcareous and some are oxidized to limonite; thin planar laminated sets (15-20 cm thick) of trough crossbedding; common involuted laminae that record penecontemporaneous deformation. The Wahweap is a slope-forming unit that is eroded into ravines and rounded, narrow interfluves, all heavily forested. Together with the underlying Straight Cliffs Formation, the Wahweap Sandstone makes a 15- km-wide bench between the Pink Cliffs of the Claron Formation, upsection, and the Gray Cliffs of the lower Straight Cliffs Formation, downsection. Approximately 305 m thick

Straight Cliffs Formation (Upper Cretaceous)--Divided into an upper half (a slope-forming unit) and a lower half (a cliff-forming unit) after Sable and Hereford (1990). Lower unit is not exposed in the Navajo Lake quadrangle. It forms gray cliffs south and west of the quadrangle and is chiefly sandstone formed in a marine shore environment. The upper unit is chiefly alternating mudstone and sandstone. The upper unit underlies wooded, stream-dissected hills south and west of the Pink cliffs.

Kscu **Straight Cliffs Formation, upper unit**--Predominantly mudstone containing numerous thin (0.3-2 m) lenticular sandstone beds; a few lenticular sandstone beds as thick as 6 m, and one or two 15 m-thick cliff-forming sandstone intervals in the upper quarter of unit. Except for the lowest 50 m, which is marine, unit is chiefly clay and sand probably deposited by streams on a coastal or fluvial plain. Ratio of mudstone to sandstone varies from 3:1 to 10:1. Mudstone is generally silty and sandy, slightly calcareous to noncalcareous, and varicolored: light gray (N7), yellowish gray (5Y 7/2), pale yellowish brown (10YR 6/2), moderate reddish brown (5YR 4/4) to brownish gray (5YR 4/1), weathers to a reddish brown (10YR 4/4, moist) and variously colored earthy slope. Sandstone interbeds are very pale orange (10YR 8/2), grayish orange (10YR 7/4), and moderate yellowish brown (10YR 5/4), weathering to light brown (5YR 5/6). Sandstone is slightly feldspathic quartz arenite; composed of fine to medium, subangular quartz grains, 4-8 percent black chert, and 10-20 percent white feldspar grains; flaggy parting; planar and trough crossbedding in sets 10-20 cm thick; firm to slightly hard. Iron oxide-cemented laminations, nodules and leaf replacement, silicified fossil wood pieces and carbonaceous plant fragments and films, and local mud pellet conglomeratic lenses. The lowest 50 m, as exposed in Schoppman Hollow, is chiefly mudstone, olive black (5 Y 2/1, moist) to dark yellowish brown (10YR 4/2, moist), containing abundant oyster and clam shells and a few high-spired snail shells, (Turritella?). This slope-forming interval probably formed in a marine bay or lagoonal environment; it contains common lenses of shellhash and scarce beds of yellowish-orange (10YR 7/6), silty, cross-laminated, very fine grained, quarztose sandstone that forms weak ledges that weather to thin slabs. Top of Kscu unit placed at top of quartzite-pebble conglomerate and gray quartzose sandstone that together are about 20 m thick and probably equivalent to Drip Tank Member of Peterson (1969), (E.G. Sable, verbal commun., 1991). Drip Tank Member is very pale yellowish brown (10YR 7/2), soft, medium- to coarse-grained sandstone and conglomerate that weather to pale yellowish brown (10YR 6/2), light gray (N7), and light olive gray (5Y 6/1) loose sand and pebbles; unit forms low knobs, spurs, and rare cliffs. Upper 2-7 m is siliceous pebble conglomerate that weathers to loose, well-rounded pebbles; 85 percent of pebbles are 2 cm diameter or less and the largest are about 6 cm. Forms 3-4 rounded ledges totaling 7 m thick that expose high-angle forset crossbeds in NW¼ sec. 34, T 37 S., R. 8 W. Well exposed 1.7 km south of mapped area near Lower Bear Spring in SE¼SE¼ sec. 22, T. 38 S., R. 9 W. Thickness of Kscu unit estimated from map, about 370 m

MAP SYMBOLS

	Contact--Dashed where approximately located or inferred
? 70	**Fault**--Bar and ball on downthrown block; dashed where approximately located, dotted where concealed, queried where uncertain. Arrow and number show dip of fault plane in degrees
2	**Strike and dip of beds**
	Base of "upper white limestone"--Informal marker bed whose top is used as top of white member of Claron Formation
	Scattered boulders of Isom breccia--Shown where surficial boulders rest on rock units other than breccia (QTbx)
	Cinder or sand and gravel pit--Loose basaltic cinders near volcanic vent; limestone and quartz sand and gravel in alluvial map unit (Qal)
	Borrow pit--Source of crushed limestone
fh	**Highway fill**--Compacted mixed soil and rock debris
af	**Artificial fill**--Hauled-in basaltic boulders and compacted soil form dam for Navajo Lake; bulldozed soil and loose rock form small dams for ponds
▲ NNL-15	**Sample location for geochemical analysis**
	Sinkholes

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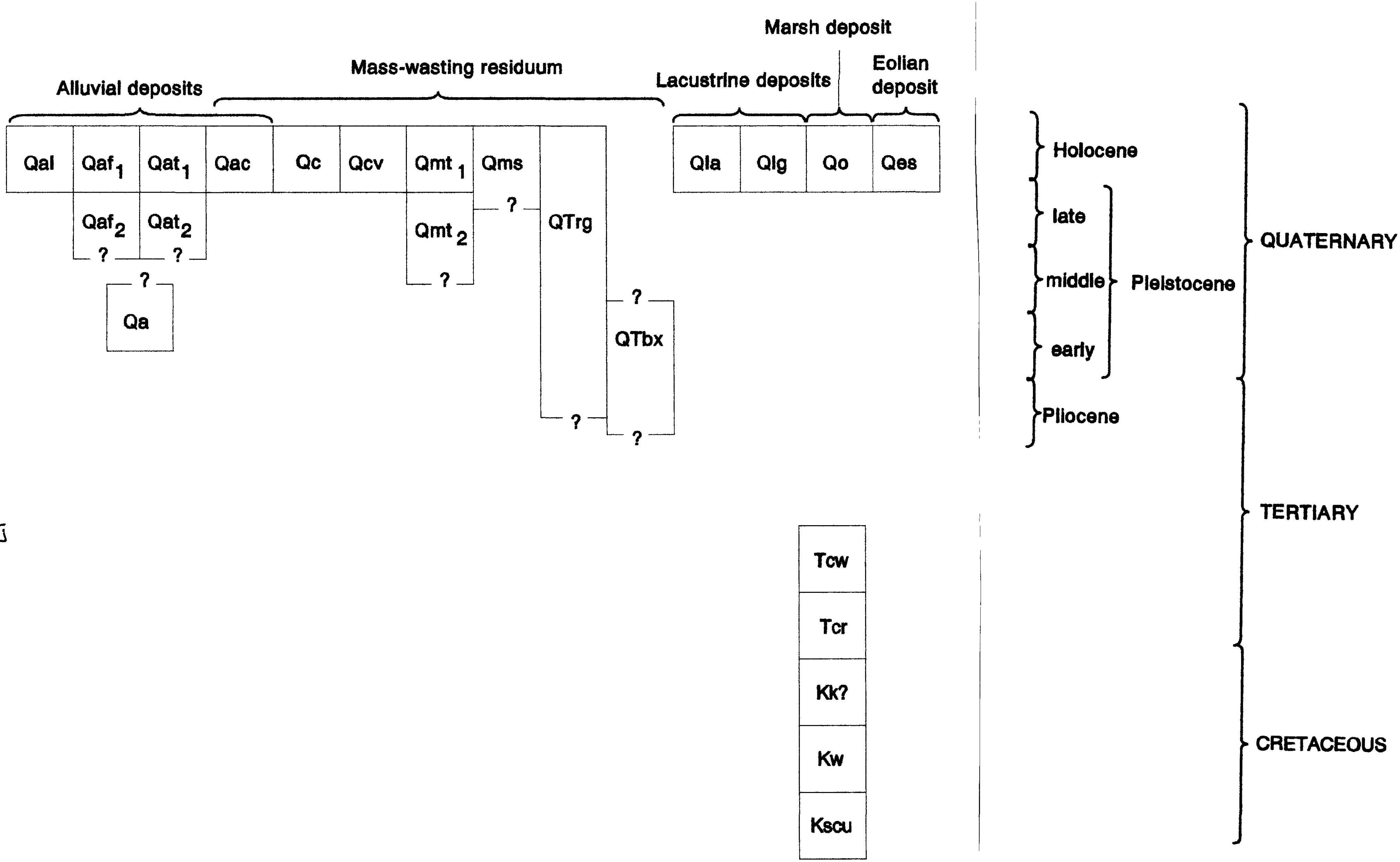
CORRELATION OF MAP UNITS



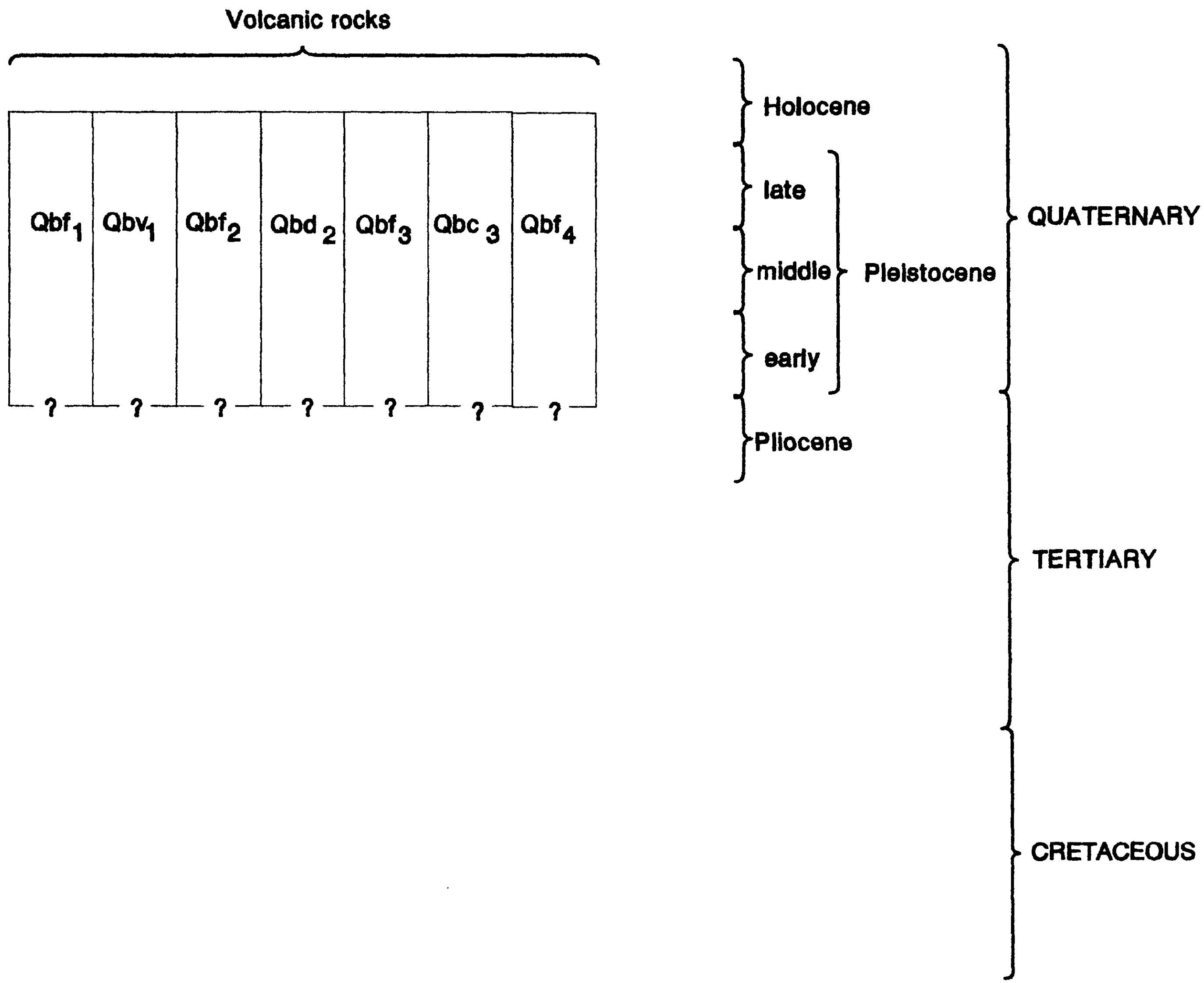

Volcanic rocks
Qbf1
Qbv1
Qbf2
Qbd 2
Qbf3
Qbc 3
Qbf4
?
Holocene
late
middle
early
Pleistocene
Pliocene
QUATERNARY
TERTIARY
CRETACEOUS

Table 1. Major- and trace-element analyses and normative composition of volcanic rocks of the Navajo Lake quadrangle, Utah

[1]Major-oxides
[Values in weight percent]

Field number	NNL-17	NNL-16	NNL-12	NNL-13	NNL-3	NNL-5	NNL-15	NNL-6	NNL-25	NNL-26	NNL-28
[2]Rock type	Basalt	Basaltic andesite	Basalt	Trachy-basalt	Basaltic trachy-andesite	Basalt	Basalt	Basalt	Basalt	Basalt	Basalt
Map Unit	Qbf_1	Qbf_1	Qbf_3	Qbf_4	Qbf_1	Qbf_3	Qbf_3	Qbf_3	Qbf_3	Qbf_3	Qbf_2
SiO_2	51.7	52.8	49.7	51.0	52.3	49.3	50.2	48.0	48.5	48.7	45.6
Al_2O_3	16.8	15.5	16.6	16.9	16.7	16.5	16.6	15.2	16.5	15.8	15.6
[3]$FETO_3$	10.0	9.31	11.0	9.61	8.28	11.1	10.1	11.0	11.4	11.4	10.5
MgO	6.41	7.72	7.88	6.99	6.63	6.47	7.23	8.58	7.19	8.32	8.29
CaO	9.28	8.07	9.9	8.02	6.77	10.0	10.5	10.7	9.12	9.45	13.0
Na_2O	3.49	3.35	3.15	3.9	4.28	3.27	3.35	3.34	3.16	3.25	3.15
K_2O	1.06	1.33	0.53	1.39	2.01	0.98	0.75	1.18	1.15	1.03	1.11
TiO_2	1.48	1.20	1.40	1.80	1.68	1.74	1.46	1.61	1.59	1.51	1.51
P_2O_5	0.37	0.38	0.28	0.47	0.55	0.42	0.37	0.69	0.50	0.47	1.08
MnO	0.16	0.14	0.17	0.15	0.12	0.17	0.16	0.17	0.17	0.17	0.19
[4]LOI	nd	0.13	nd	nd	nd	nd	nd	nd	1.14	0.04	nd
Total	100.75	99.93	100.61	100.23	99.32	99.95	100.72	100.47	100.42	100.14	100.03

[5]Normative composition
[Based on analyses recalculated to 100 percent volatile-free oxides]

q	0	0	0	0	0	0	0	0	0	0	0
or	6.22	7.88	3.11	8.2	11.96	5.79	4.4	6.94	6.84	6.08	6.56
ab	29.31	28.4	26.49	32.92	36.46	27.68	28.14	22.18	26.92	27.47	12.36
an	26.84	23.37	29.41	24.44	20.56	27.46	27.84	22.89	27.62	25.45	25.14
ne	0	0	0	0	0	0	0	3.22	0	0	7.74
di-wo	6.87	5.95	7.34	5.09	4.03	8.11	8.97	10.63	6.11	7.65	13.48
di-en	4.26	3.89	4.51	3.46	2.92	4.89	5.69	6.85	3.65	4.74	8.72
di-fs	2.21	1.65	2.41	1.23	0.74	2.79	2.7	3.07	2.14	2.46	3.85
hy-en	8.63	14.98	6.08	4.83	5.35	3.41	3.38	0	3.28	0.63	0
hy-fs	4.48	6.38	3.25	1.71	1.36	1.95	1.61	0	1.92	0.32	0
ol-fo	2.08	0.28	6.25	6.36	5.86	5.48	6.17	10.1	7.78	10.75	8.36
ol-fa	1.19	0.13	3.68	2.48	1.64	3.45	3.23	4.99	5.02	6.14	4.07
mt	4.29	3.92	4.18	4.77	4.64	4.7	4.26	4.49	4.51	4.36	4.36
il	2.79	2.28	2.64	3.41	3.21	3.31	2.75	3.04	3.04	2.86	2.87
ap	0.85	0.88	0.64	1.09	1.28	0.97	0.85	1.59	1.17	1.09	2.5

[6]Trace elements
[Values in parts per million]

Nb	13	17	8.6	18	30	27	16	31	20	22	56
Rb	17	19	10	21	21	18	15	20	12	16	17
Sr	750	820	425	580	810	550	580	1100	710	680	1400
Zr	200	200	156	255	245	188	182	200	184	178	220
Y	27	24	25	29	21	28	30	24	24	24	27
Ba	790	1000	445	425	880	640	630	1100	940	740	2000
Ce	84	73	46	77	79	54	48	146	80	74	196
La	39	34	22	31	23	24	22	56	27	31	88
Cu	35	40	73	27	37	84	63	87	68	64	95
Ni	59	134	116	124	122	67	65	144	110	116	73
Zn	77	80	85	64	61	76	77	80	82	55	53
Cr	158	275	270	210	158	158	188	305	192	235	160

[1] Major elements determined by wavelength dispersive X-ray spectroscopy; J.E. Taggart, analyst.
[2] Nomenclature based on total alkali and silica contents, following LeBas and others (1986).
[3] $FeTO_3$ = total iron as Fe_2O_3
[4] LOI= loss on ignition
[5] Total iron as Fe_2O_3; Fe_2O_3 in normative analyses calculated as $TiO_2 + 1.5$, following Irvine and Baragar (1971).
[6] Trace elements deteremined by energy dispersive X-ray spectroscopy; J. Kent, analyst.

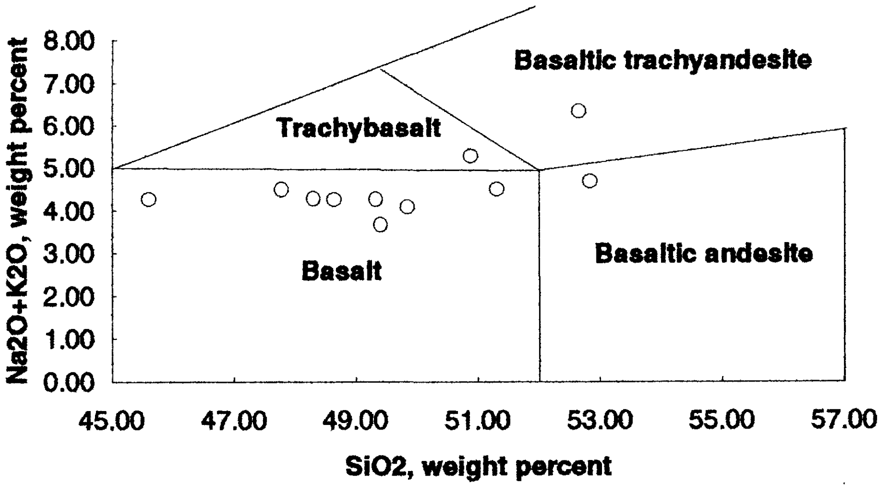


Figure 1. Total alkali versus silica variation diagram for basaltic rocks of the Navajo Lake quadrangle Analyses plotted on a volatile-free basis. Nomenclature after LeBas and others (1986).