Department of Environment and Natural Resources
Division of Financial and Technical Assistance
Geological Survey Program
7.5 Minute Series Geologic Quadrangle Map 19

Geologic Map of the Lead Quadrangle, South Dakota

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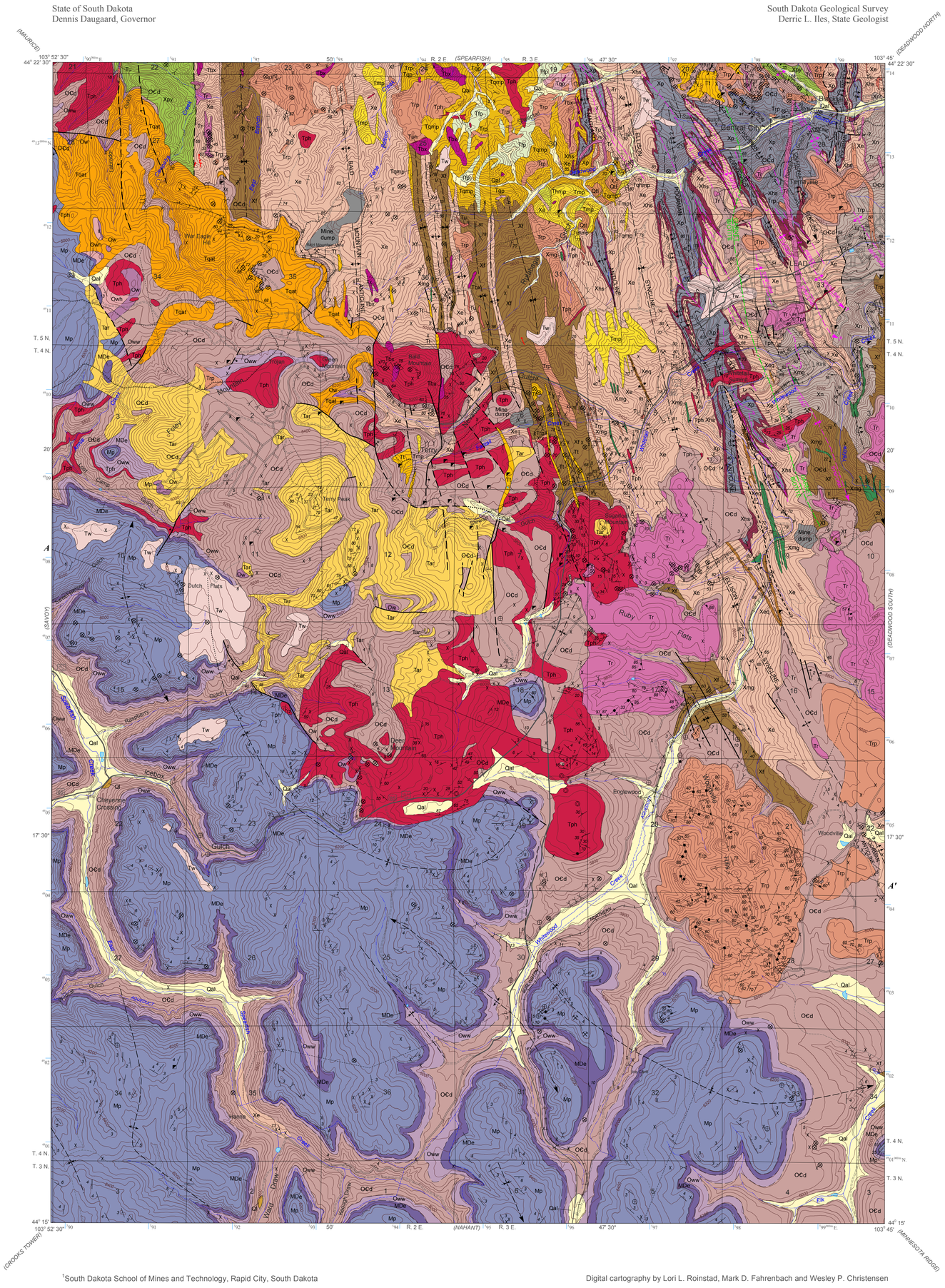
2013

Prepared in cooperation with the South Dakota School of Mines and Technology, Rapid City, South Dakota

State of South Dakota
Dennis Daugaard, Governor

South Dakota Geological Survey
Derric L. Iles, State Geologist



[1]South Dakota School of Mines and Technology, Rapid City, South Dakota

Digital cartography by Lori L. Roinstad, Mark D. Fahrenbach and Wesley P. Christensen

Map base modified from U.S. Geological Survey 1:24,000-scale Lead digital line graph.
Projection is Universal Transverse Mercator, Zone 13N.
Datum is 1983 North American.

The South Dakota Geological Survey Program, Department of Environment and Natural Resources, engages in an ongoing data collection and interpretation process. An outcome of that process is to reflect those interpretations on maps such as this one. Reasonable efforts have been made to ensure that this map accurately reflects the source data used in its preparation. This map is date specific. As additional data become available, geologic interpretations may be revised and the map may be updated by the Geological Survey Program. This map should not be enlarged or otherwise used in an attempt to interpret more detail than can be seen at a scale of 1:24,000.

SCALE 1:24,000

1 0.5 0 1 Mile

1,000 0 1,000 2,000 3,000 4,000 5,000 6,000 7,000 Feet

1 0.5 0 1 Kilometer

Contour Interval 40 Feet

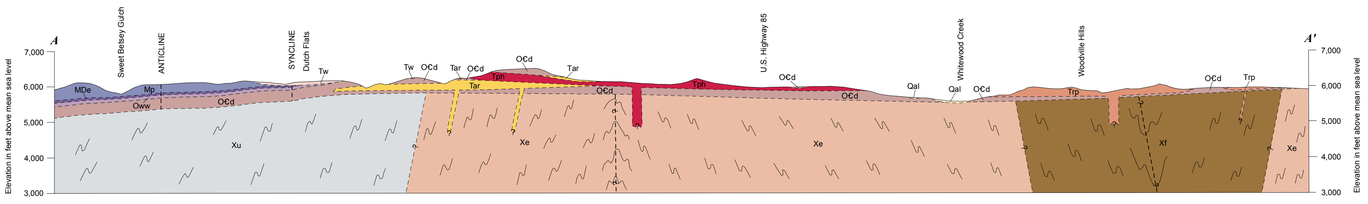
NORTH

0° 53' 15.5 MILS

8° 29' 148 MILS

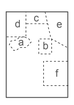
UTM GRID AND 2012 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

Quadrangle location



Index to sources of geologic data

(letters correspond to those listed in Selected References)



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Acknowledgements

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EXPLANATION

Quaternary

Qal — **Alluvium** - Unconsolidated to loosely consolidated; clasts to boulder-size. Deposited in present-day stream drainages. Estimated maximum thickness 40 ft (12.2 m)

Ql — **Landslide** - Unconsolidated, locally derived bedrock debris to boulder-size. Often associated with steep slopes of the Winnipeg Formation

Qtl — **Talus** - Unconsolidated, locally derived, angular bedrock debris to boulder-size. Typically on steep slopes of Tertiary intrusive rocks. Normally devoid of soil or tree cover

Unconformity

Oligocene to Eocene

Tw — **White River Group** - Unconsolidated to moderately consolidated. Clasts to boulder-size, dominantly of Precambrian rock types with Paleozoic sedimentary and Tertiary igneous rocks. Fine-grained matrix and bentonitic clay content variable. Estimated thickness up to 230 ft (70.1 m), with thickest deposits associated with erosional channels

Unconformity

Tertiary

Eocene to Paleocene

Tph — **Phonolite** - Light- to dark-green, greenish-gray to gray. Massive to layered. Composition varies from alkali trachyte to phonolite. Very fine holocrystalline to aphanitic groundmass of approximately 40-65 percent alkali feldspar, 23 percent zoned aegirine-augite, and 5 percent nepheline and leucite. Groundmass contains 10-45 percent phenocrysts dominantly of euhedral sanidine or nepheline up to 1.4 in (35 mm) across. Typically has trachytic texture from aligned feldspar laths, or may have flow layering, especially along contacts. Accessory minerals include minor biotite, magnetite, apatite, ilmenite, and titanite. Hematite, clay, calcite, and zeolite occur as alterations (Larsen, 1977; Usiriprisan, 1979; Harris, 1991). A dike in the Homestake mine has a K-Ar date of 58.2 +/- 1.7 Ma (McDowell, 1971)

Tbx — **Breccia** - Reddish- and yellowish-brown to beige dikes and irregularly shaped bodies of clast supported heterolithic breccia. Composed of approximately 40-60 percent angular to rounded clasts of Tertiary igneous rocks and Precambrian schist and quartzite as much as 6 in (15.2 cm) diameter in a very finely-crystalline to aphanitic, rhyolitic, quartz-feldspar matrix. Typically oxidized, limonitic and iron-stained, or hydrothermally altered (Larsen, 1977)

Tr — **Rhyolite** - Light-gray, yellowish-brown, pinkish, to white. Finely-crystalline to aphanitic groundmass of 60-65 percent potassium feldspar and 25-35 percent quartz, contains up to 25 percent zoned, euhedral to subhedral phenocrysts of quartz up to 0.16 in (4 mm) diameter and feldspar as much as 0.1 in (2.5 mm) diameter. Some feldspars are replaced by quartz. Accessory minerals include minor magnetite and garnet. Sericite, hematite, and limonite occur as alterations. May have breccia along contacts, flow layering from aligned biotite crystals, or sheeting from closely spaced fractures parallel to the flow layering (Usiriprisan, 1979)

Trp — **Rhyolite porphyry** - Light-gray, reddish- to yellowish-brown, to pinkish. White where weathered, with feldspar phenocrysts nearly indistinguishable from the finely-crystalline to aphanitic groundmass of 40-50 percent potassium feldspar, 8-15 percent oligoclase, and 30 percent quartz. Contains 30-50 percent euhedral phenocrysts of orthoclase, sanidine, plagioclase, and albite up to 0.2 in (5 mm) across. Has minor anhedral, partially resorbed quartz, and 4-6 percent biotite as much as 0.08 in (2 mm) diameter that may be replaced by chlorite. Accessory minerals include minor magnetite and garnet. Hematite, limonite, calcite, and clay occur as alterations. May have flow layering from aligned biotite crystals (Larsen, 1977; Usiriprisan, 1979)

Tar — **Alkali rhyolite** - Light-gray, reddish-brown to pinkish. Includes aegirine rhyolite, quartz-aegirine porphyry, and grorudite. Groundmass of finely-crystalline quartz and alkali feldspar is often partially replaced by quartz, aegirine-augite, and albite. Contains 10-50 percent phenocrysts of subhedral and euhedral sanidine, albite, and orthoclase as much as 0.2 in (5 mm) in diameter. Some feldspars are replaced by quartz and aegirine-augite. Accessory minerals include minor biotite, phlogopite, and sulfides. Feldspars are locally altered to clay, sericite, and natrolite (DeWitt and others, 1986; Harris, 1991). An intrusive near Terry Peak has a K-Ar date of 58.5 +/- 4.3 Ma (McDowell, 1971)

Tqp — **Quartz porphyry** - Leucocratic, light-gray to tan. Aphanitic groundmass of alkali feldspar contains up to 50 percent medium to very coarsely crystalline phenocrysts of alkali feldspar, and gray, tear drop-shaped quartz that are partially resorbed. Exposures are highly weathered. Most feldspar phenocrysts are replaced with clay and iron oxide. Mafic minerals are absent. Similar in appearance to rhyolite porphyry (Larsen, 1977)

Tfp — **Feldspar porphyry** - Gray where fresh, purplish-pink and green where weathered. Composed of 34-50 percent clear to grayish, subhedral to anhedral anorthoclase phenocrysts 0.2-0.31 in (5-8 mm) diameter in a dark-colored, aphanitic, potassium feldspar groundmass. Contains 3-8 percent lath-shaped oligoclase and aegirine crystals, and rounded quartz phenocrysts 0.04-0.08 in (1-2 mm) long. Very fine-grained disseminated pyrite occurs near contacts with quartz monzonite porphyry. Small hematite-filled, lath-shaped voids are from altered aegirine. Groundmass typically alters to iron oxide and clay (Larsen, 1977)

Tt — **Trachyte** - Tan to reddish-brown, iron-stained. Finely-crystalline, mesocratic to leucocratic groundmass of orthoclase, sanidine, quartz, and biotite typically has a trachytic texture. Contains up to 20 percent lath-shaped phenocrysts of sanidine, orthoclase, and anorthoclase as much as 0.2 in (5 mm) diameter, and minor aegirine-augite, nepheline, and biotite. May contain unoxidized and oxidized pyrite, minor clay and calcite replacing mafic minerals, and zeolites (Larsen, 1977)

Tqat — **Quartz alkali trachyte** - Light-gray where fresh, weathers tan to reddish-brown. Groundmass of microcrystalline to cryptocrystalline potassium feldspar, aegirine-augite, and partially resorbed quartz contains 30-60 percent euhedral albite or sanidine phenocrysts as much as 0.39 in (10 mm) diameter. Some phenocrysts are zoned, hydrothermally altered, and replaced by sericite, barite, carbonate, iron oxides, or pyrite. Cavities formed from alteration of mafic minerals or entrapment of gas bubbles are abundant. Accessory minerals include rutile, titanite, and apatite (Harris, 1991)

Thmp — **Hornblende monzonite porphyry** - Melanocratic, porphyritic with an aphanitic groundmass. Contains approximately 60 percent plagioclase and 30 percent ferromagnesian grains averaging 0.04 in (1 mm) diameter. Ferromagnesian grains may be altered to magnetite and chlorite. Poorly exposed, generally occurring only as cobbles in soil

Tqhmp — **Quartz-bearing hornblende monzonite porphyry** - Light- to medium-gray, porphyritic, with an aphanitic groundmass. Contains 25 percent plagioclase, 5-20 percent biotite, and 1-5 percent hornblende phenocrysts less than 0.2 in (5 mm) diameter, and minor quartz. Locally, plagioclase is typically altered to sericite, and the ferromagnesian grains to calcite, chlorite, and magnetite

Tmp — **Monzonite porphyry** - Leucocratic, gray where fresh, tan, red, yellow to white where weathered. Phaneritic, granular groundmass of plagioclase and alkali feldspar includes quartz that is commonly anhedral and overgrows feldspars. Contains 50-70 percent zoned, euhedral to subhedral, plagioclase and alkali feldspar phenocrysts to over 0.39 in (10 mm) diameter, and 3-5 percent quartz phenocrysts as much as 0.16 in (4 mm) diameter. Sulfide-bearing where fresh, highly oxidized where exposed, with hematite and clay replacing many plagioclase phenocryst cores. Aggregates of pyrite and calcite replace original mafic minerals. Gradational into quartz monzonite porphyry, but phenocrysts are more abundant and larger than 0.2 in (5 mm) diameter (Larsen, 1977)

Tqmp — **Quartz monzonite porphyry** - Gray where fresh, red, yellow, to white where weathered; typically iron-stained. Phaneritic groundmass is finely crystalline, equigranular, quartz-plagioclase-alkali feldspar. Contains approximately 10 percent potassium feldspar and 40 percent plagioclase as euhedral to subhedral, zoned phenocrysts as much as 0.2 in (5 mm) diameter, and 10-15 percent euhedral quartz. Some feldspars are altered to clay, sericite, and calcite. Contains abundant resorbed quartz. Pyrite, chlorite, calcite, and clay replace ferromagnesian minerals. May have up to 5 percent pyrite and 0.1 percent molybdenite, especially along argillized and silicified contacts with schist and amphibolite. Gradational into monzonite porphyry, but phenocrysts are less abundant and smaller than 0.2 in (5 mm) diameter (Larsen, 1977)

Tu — **Undifferentiated Tertiary igneous rocks** - Leucocratic to mesocratic, aphanitic to porphyritic, hypabyssal intrusive rocks. Includes phonolitic, rhyolitic, trachytic, and latitic rocks

Intrusive Contact

Mississippian / Devonian

Lower Mississippian

Mp — **Pahasapa Limestone** - White, beige, to gray massive limestone and dolomitic limestone. Finely- to coarsely-crystalline. Contains thin lenses and beds of gray to brown chert and local solution breccia. Vuggy, with caves occurring mainly in the upper third. Forms prominent cliffs. Exposed thickness approximately 450 ft (137.2 m)

Upper Devonian

MDe — **Englewood Limestone** - Pink, gray, to purple-gray shale grading upward into purple- to pinkish-gray argillaceous limestone and dolomite. Laminated to medium-bedded, very finely- to medium-crystalline; bioturbated. Thickness 40-60 ft (12.2-18.3 m)

Disconformity

Ordovician

Upper Ordovician

Oww — **Whitewood Limestone-Winnipeg Formation (undifferentiated)** - Includes the Winnipeg Formation and Whitewood Limestone

Owh — **Whitewood Limestone** - Variegated yellowish-brown, brownish-orange, to gray dolomitic limestone and dolomite. Finely- to medium-crystalline. Thin-bedded to massive with thin shale partings; bioturbated. Thickness 40-80 ft (12.2-24.4 m)

Ow — **Winnipeg Formation** - Includes the Ice Box Shale Member - 30-45 ft (9.1-13.7 m) of greenish-gray to gray fissile shale containing small, black phosphatic pebbles, grading upward into the Roughlock Siltstone Member - 25-40 ft (7.6-12.2 m) of tan to yellowish-gray, calcareous siltstone and sandstone. Combined thickness 55-85 ft (16.8-25.9 m)

Disconformity

Cambrian

Lower Ordovician / Upper Cambrian

OCd — **Deadwood Formation** - Brown, gray, to green basal conglomerate and massive sandstone overlain by glauconitic shale, siltstone, sandstone, and minor intraformational conglomerate. Middle and upper beds of laminated to thick-bedded, brown, gray, to dark-green, bioturbated, glauconitic shale and sandstone, intraformational conglomerate, and limestone. Approximately 15-25 ft (4.6-7.6 m) of medium-bedded to massive "*Scolithus* sandstone" occurs at the top. Thickness 250-400 ft (76.2-121.9 m)

Unconformity

Precambrian

Lower Proterozoic

Xmg — **Metagabbro** - Grayish-green to greenish-black, finely- to medium-crystalline dikes and sills composed of plagioclase, hornblende, biotite, and calcite. May have a schistose appearance. Protolith is gabbro

Xf — **Flag Rock Formation** - Light-gray to greenish-gray sericitic schist, laminated pyritic and graphitic phyllite, and hornblende-plagioclase schist. Locally with pillow structures, streaked graphitic quartzite, metachert, and metamorphosed carbonate iron-formation with cummingtonite, biotite, and chlorite similar in appearance to the Homestake Formation. Protolith is pillow basalt with interflow deposits of siltstone, carbonaceous shale, chert, and iron carbonate. Thickness up to 5,250 ft (1,600.2 m) in the area of the Homestake Mine (Slaughter, 1968; Caddey and others, 1991)

Unconformity

Xn — **Northwestern Formation** - Gray to dark-gray phyllite, slate, and biotite-sericite schist. Thin- to medium-bedded, however laminations and bedding are rare. May contain minor tourmaline and titanite. Protolith is shale, carbonaceous shale, and siltstone. Thickness up to 4,265 ft (1,299.9 m) in the area of the Homestake Mine (Caddey and others, 1991)

Xe / XeQ — **Ellison Formation** - Xe - Light-gray to black, banded, well foliated, sericite-quartz phyllite; light-brown, thick-bedded to massive, biotite-quartz phyllite; light-gray to pale-brown quartz-mica schist; and minor amphibolite. Conglomerate beds rare. Few thin beds of limestone occur in the area of Lead and increase in abundance to the south. Xeq - Quartzite, light to dark-gray. Probably derived from chert. Locally contains minor graphite and sulfides. Formation protolith is sandstone with siltstone and shale. Thickness approximately 1,312-4,921 ft (399.9-1,499.9 m) in the area of the Homestake Mine (Caddey and others, 1991). A metatuff in the lowermost Ellison Formation has an age of 1,974 +/- 8 Ma (Redden and others, 1990)

Xhs — **Homestake Formation** - Gray, brown, to green carbonate-facies iron-formation with chloritic and biotitic schist and phyllite and thin quartzite beds. Typically occurs as olive-green to gray-green siderite phyllite with moderately well developed graphite-rich layers as much as 0.2 in (5 mm) thick in the upper greenschist facies, and as olive-green to dark-green cummingtonite-grunerite schist with minor chlorite and almandite in the lower amphibolite facies. Thin-bedded to massive, with lenses of chloritic schist, thin metachert beds, white quartz veins, and approximately 3 ft (0.91 m) of layered chloritic schist transitional into the Ellison and Poorman Formations. Gold is associated with a quartz-chlorite-pyrrhotite-arsenopyrite assemblage. Original thickness approximately 66-98 ft (20.1-29.9 m) before metamorphism. Presently 0-164 ft (0-49.9 m) thick, increasing to 410 ft (124.9 m) thick in fold hinges. Protolith is carbonate iron-formation with interbedded shale and chert (Caddey and others, 1991)

Xp — **Poorman Formation** - Xp - Light-gray to black, graphitic phyllite, sericite- and biotite-rich carbonate, and quartz-bearing phyllite. Fine-grained, laminated to thin-bedded with prominent banding, especially in the upper 100 ft (30.5 m). Locally with white to gray metachert layers containing variable amounts of graphite, ankerite, garnet, tremolite, and streaks and blebs of pyrrhotite. Chlorite increases around quartz veins, amphibolite masses, and near the Homestake Formation. Protolith is siltstone, calcareous and carbonaceous shale, tuff, carbonate, and chert. Thickness 656-3,280 ft (199.9-999.9 m) in the area of the Homestake mine (Slaughter, 1968; Caddey and others, 1991)

Xpy — **Yates unit of the Poorman Formation** - Xpy - Dark-green, massive to faintly banded, finely-crystalline, hornblende-plagioclase schist. Contains white calcite bands and veinlets to 0.79 in (2 cm) thick. Locally, partially to completely replaced by chlorite-calcite-biotite. Contains interflow deposits of graphitic quartz-sericite phyllite, grunerite iron-formation without sulfides, and metachert. Protolith is tholeiitic basalt, tuff, siltstone, and shale. Yates unit in the northwest corner of the map by Labrador Gulch may not be equivalent to the Yates unit at other areas. Thickness 1,968-3,937 ft (599.8-1,199.9 m) in the area of the Homestake mine (Caddey and others, 1991)

Xu — **Undifferentiated Early Proterozoic rocks** - Shown only in cross section

FAULTS

Fault — Long dashed where approximately located; short dashed and queried where inferred in cross section; bar and ball on downthrown side

FOLDS (Laramide)

Anticline — Location of trace of axial surface and direction of plunge. Long dashed where approximately located; short dashed where inferred in cross section; dotted where concealed

Syncline — Location of trace of axial surface and direction of plunge. Long dashed where approximately located; short dashed where inferred in cross section; dotted where concealed

FOLDS (Early Proterozoic)

D_1 FOLDS

Generalized interpretation of earliest folds based on various level maps prepared by Homestake mine geologists from underground workings and extensive drill-hole data outside of the original mine area. Available data on level maps is limited to the Ellison Formation lower contact, Homestake Formation, and Poorman Formation including the Yates unit. Extension of the Poorman Anticline southeast of Whitetail Summit is uncertain due to later refolding and extensive shear displacement. Smaller D_1 folds are generally not shown, especially where coinciding with younger folds and modified by later shearing. Original names of structures have been retained in most of the Homestake mine area, but some names have been changed in the present interpretation

Anticline — Location of trace of axial surface and generalized direction of plunge. Long dashed where approximately located; short dashed where inferred in cross section; dotted where concealed; queried where uncertain

Syncline — Location of trace of axial surface and generalized direction of plunge. Long dashed where approximately located; short dashed where inferred in cross section; dotted where concealed; queried where uncertain

Overturned anticline — Location of trace of axial surface, dip direction of limbs, and generalized direction of plunge. Long dashed where approximately located; dotted where concealed; queried where uncertain

Overturned syncline — Location of trace of axial surface, dip direction of limbs, and generalized direction of plunge. Long dashed where approximately located; dotted where concealed; queried where uncertain

MAJOR D_2 FOLDS

Trace of folds based on subsurface data. Original names of structures have been retained in most of the Homestake mine area, but some names have been changed in the present interpretation

Antiform — Location of trace of inferred axial surface and generalized direction of plunge. Long dashed where approximately located; dotted where concealed; queried where uncertain

Synform — Location of trace of inferred axial surface and generalized direction of plunge. Long dashed where approximately located; dotted where concealed; queried where uncertain

MINOR D_2 AND YOUNGER FOLDS

Includes smaller folds formed during development of major D_2 structures and younger folds developed largely by localized shear zones mainly in the Lead synform. Only generalized traces of axial surfaces are shown. Plunges commonly vary, even in individual folds. Small sheath folds modify some structures. All minor D_2 folds are not shown at this map scale

Undifferentiated fold — Location of trace of inferred axial surface. Long dashed where approximately located; dotted where concealed

STRIKE AND DIP OF BEDDING

Inclined

Inclined — Ball indicates top direction of beds known to be in dip direction

Vertical

Horizontal

Overturned — Where direction of younging is known; top direction of beds is opposite dip direction

Top of bed — Direction of younging indicated by sedimentary structures

STRIKE AND DIP OF FOLIATION

Inclined

Vertical

STRIKE AND DIP OF FLOW FOLIATION IN IGNEOUS ROCKS

Inclined

Vertical

Horizontal

STRIKE AND DIP OF FRACTURES

Inclined

Vertical

LINEAR STRUCTURES

Lineation — Mineral lineation in Tertiary igneous rocks; showing bearing and plunge

Minor fold — Showing bearing and plunge. Related to D_2 and younger folds

Quartz vein

BIOTITE / GARNET — Metamorphic isograd

OTHER FEATURES

Mine dump

Open pit mine or glory hole

Gravel pit

Mine shaft

Mine adit or cave

Trench

Group of prospect pits

Prospect pit

Outline of open pit mine

Outline of mine waste pile