U.S. DEPARTMENT OF THE INTERIOR
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GEOLOGIC MAP OF THE EATON RESERVOIR QUADRANGLE, LARIMER COUNTY, COLORADO, AND ALBANY COUNTY, WYOMING

By
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2008

SCIENTIFIC INVESTIGATIONS MAP 3029
Version 1.0

Base from U.S. Geological Survey, 1967
Polyconic projection
10,000-foot grids based on Colorado coodinate system, north zone, and
Wyoming coordinate system, east zone
1,000-meter Universal Transverse Mercator
grid ticks, zone 13
1927 North American Datum

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Map 3029, scale: 1:24,000.

INTRODUCTION

New geologic mapping of the Eaton Reservoir 7.5' quadrangle defines geologic relationships in the northern Front Range along the Colorado/Wyoming border approximately 35 km south of Laramie, Wyo. Previous mapping within the quadrangle was limited to regional reconnaissance mapping (Tweto, 1979; Camp, 1979; Burch, 1983) and some minor site-specific studies (Carlson and Marsh, 1986; W. Braddock, unpub. mapping, 1982). Braddock and others (1989) mapped the Diamond Peak 7.5' quadrangle to the east, Burch (1983) mapped rocks of the Rawah batholith to the south, W. Braddock (unpub. mapping, 1981) mapped the Sand Creek Pass 7.5' quadrangle to the west, and Ver Ploeg and Boyd (2000) mapped the Laramie 30' x 60' quadrangle to the north. Field work was completed during 2005 and 2006 and the mapping was compiled at a scale of 1:24,000. Minimal petrographic work and isotope dating was done in connection with the present mapping, but detailed petrographic and isotope studies were carried out on correlative map units in surrounding areas as part of a related regional study of the northern Front Range. Classification of Proterozoic rocks is primarily based upon field observation of bulk mineral composition, macroscopic textural features, and field relationships that allow for correlation with rocks studied in greater detail outside of the map area.

DESCRIPTION OF MAP UNITS

[Unit symbols for Proterozoic rocks, in some cases, utilize nonstandard symbols which are intended to emphasize composition while differentiating broadly accepted lithodemic unit names. Lower case letters after the age designation indicate rock composition and textural features whereas capitol letters indicate major named intrusive body or rock suite.]

Artificial fill (latest Holocene)

Alluvium (Holocene)—Poorly sorted coarse sand, gravel, and boulders in stream channels, flood plains, and low terraces. Flood plain and terrace deposits are generally less than 5 m above present stream level. In the Eaton reservoir area, unit locally includes some lake sediments. Unit locally includes colluvium not mapped separately. Clasts composed primarily of granite, amphibolite, hornblende gneiss, biotite gneiss, felsic gneiss, and pegmatite and coarse quartz-rich intrusive rocks

Colluvium (Holocene to middle? Pleistocene)—Nonsorted clay, silt, sand, and angular to subrounded clasts ranging in size from granules to large boulders. Includes deposits transported downslope from outcrop by sheet wash, landslide, debris flow, hyperconcentrated flow, rock fall, and periglacial processes. In the southeastern corner of map area, includes large boulder field talus deposits, with no matrix material, composed of large angular boulders of granitic material derived from flanks of Black Mountain just south of map area

Pediment deposits (middle Pleistocene)—Poorly stratified and nonsorted to poorly sorted, clast- and locally matrix-supported gravelly and sandy alluvial sediment that overlies gently sloping surfaces cut on Fountain Formation (PPf) and Sherman Granite (YgSH) at northern end of quadrangle. Composition of clasts generally reflects underlying bedrock unit with predominantly granite-rich pebble gravel and pebbly sand derived from Sherman Granite (YgSH) to east of Running Water Creek, and arkosic sand and gravel derived from Fountain Formation (PPf) to west. Unit locally includes minor unmapped sheetwash deposits, colluvium, and probable hyperconcentrated-flow deposits. Lower limit of pediment surface is about 18 m above Sand Creek to north of quadrangle boundary. Estimated thickness is 1–5 m

Fountain Formation (Lower Permian and Pennsylvanian)—Only lower part of formation exposed in map area. Maroon to pink and light greenish-gray, coarse-grained, trough crossbedded arkosic fluvial sandstone and conglomerate interbedded with minor amounts of pink and light green micaceous siltstone and mudstone. Sandstone within upper part of formation, exposed to west of map area, is finer grained and conglomerate beds are thinner and less common. Lower part of formation has very few resistant beds and forms low rolling hills in northwestern corner of map area. Beds dip gently to northwest, but are poorly exposed. Unit lies unconformably on Proterozoic granite (YgSH). A thin discontinuous dolomitic limestone bed containing chert nodules is exposed at base of unit just northeast of where the road crosses Sand Creek (section 30, T. 12 N., R. 74 W.). Ichthyolith fossils indicate a maximum age of Mississippian for the limestone but have a long range and could just as well be Pennsylvanian (A. Harris, written commun., 2005). Sando and Sandberg (1987) assigned similar limestones exposed at northern end of Laramie Range in Wyoming to Big Goose Member of Madison Limestone of Peale (1893). Top of unit not exposed in map area, but estimated thickness of unit just west of quadrangle near Sand Creek Pass is 97 m. Top of unit is marked by an erosional unconformity within area which indicates episodic nature of uplift along flanks of Ancestral Front Range which caused beveling and overlapping of successively younger sequences (Maughan, 1993). West of Bull Mountain 12 km west of map area, where formation is thickest within Laramie River Valley, Camp (1979) reports a thickness of 169 m for lower unit of formation and a total thickness of 212 m

Kimberlite (Devonian?)—Black to greenish-gray and brown (oxidized) hypabyssal, macrocrystic phlogopite kimberlite forms en echelon dikes ranging from 4 m to less than 1 cm (stringer kimberlite) in width and as much as 1 km long. Rock consists of medium- to coarse-grained serpentinized olivine, phlogopite, garnet with kelphytic rims, minor ilmenite or chrome diopside, and trace amounts of crustal xenoliths, eclogites, ilmenite megacrysts, and rare, highly serpentinized peridotite nodules within a fine-grained micaceous matrix. Groundmass composed of phlogopite, serpentine, altered ilmenite and spinel, perovskite, and apatite. Carbonate and silicic alteration and oxidation are variable across the deposit. Kimberlite contains sparse diamonds that are characterized by high proportions of aggregate and colorless stones as much as approximately 4 mm in diameter (Carlson and Marsh, 1986). Contact with surrounding amphibolite and hornblende gneiss (Xh) is generally sharp. Minor serpentine and carbonate veinlets extend as much as 1 m out from contact into country rocks. Dike locations based upon soil sampling, very low frequency electromagnetic surveys, and exploratory trenching by Carlson and Marsh (1986). Devonian age based upon fragments of Ordovician and

Silurian limestone described by Chronic and others (1969) in other exposures in State Line kimberlite field

Granite of Log Cabin batholith (Mesoproterozoic)—Gray to pink, medium- to coarse-grained, equigranular to seriate porphyritic biotite syenogranite and monzogranite. Composed of quartz, microcline, plagioclase, and biotite, minor zircon, magnetite, and apatite, and accessory allanite, sphene, and secondary muscovite. Lacks hornblende in contrast to older Sherman Granite (YgSH). Composition is granitic but ranges to granodiorite in some exposures. Within map area unit generally contains characteristic large (as much as 4 cm) euhedral microcline phenocrysts. Contact with surrounding granite of Rawah batholith (XgR) is poorly exposed within map area, but unit grades to biotite-poor, medium-grained equigranular facies within about 15 m of contact suggesting a chill zone along outer margins of intrusive body. Burch (1983) describes a sharp to gradational contact in South Bald Mountain quadrangle south of map area. There contact zone is 0.5 km wide and composed of small bodies of porphyritic and fine-grained equigranular granite of Log Cabin batholith (YgLC) and rounded inclusions of granite of Rawah batholith (XgR) as much as several meters in diameter within 100 m of contact. Contact zone is intruded by abundant pegmatite, quartz veins, fine-grained dikes, and biotite-rich hybrid granitoid rocks. Whole-rock Rb/Sr age is 1,390±30 Ma (Braddock and others, 1989)

Pegmatite (Mesoproterozoic? and Paleoproterozoic)—Coarse- to very coarse-grained, white to pink, inequigranular leucogranitic intrusions forming dikes and small bodies. Contains quartz, plagioclase, microcline, and variable amounts of biotite and (or) muscovite. Graphic granite texture is common and brecciation is ubiquitous. Unit is poorly exposed and generally mapped based upon abundance in float material. Locally may include aplitic dikes. Age is poorly constrained within map area where unit only intrudes Paleoproterozoic rocks. In southern part of map area, granite of Rawah batholith (XgR) is dissected by widespread, feldspar-rich, mica-poor pegmatite dikes that cannot easily be mapped as individual bodies (shown as pattern) in southeast corner of map. These occurrences are related to assimilation of large inclusions of country rock within Paleoproterozoic Rawah batholith (XgR), so a Paleoproterozoic age is preferred. In surrounding areas, Paleoproterozoic pegmatites related to Rawah batholith, as well as Mesoproterozoic pegmatites related to Log Cabin batholith, have been documented (Peterman and others, 1968)

Mafic dikes (Mesoproterozoic)—Gray to black, fine- to medium-grained, sparsely porphyritic, ophitic to subophitic hornblende-biotite diorite and diabase dikes that form a northwest trending dike swarm across much of northern Front Range. Composition variable locally and regionally, but generally consists of zoned and altered plagioclase phenocrysts in a matrix of pyroxene, hornblende, biotite, iron oxides, and alteration products. Dikes mostly exposed in Sherman Granite (YgSH), but cut Paleoproterozoic metamorphic rocks in some locations. Southeast of map area in Livermore Mountain quadrangle, correlative dikes are cut by main phase of granite of Log Cabin batholith (YgLC) and by pegmatites of similar age (Braddock and Connor, 1988). Extent and orientation of dikes is largely mapped from aerial photographs in conjunction with field observations

Sherman Granite (Mesoproterozoic)—Red to pink, coarse-grained, equigranular to mildly porphyritic hornblende-biotite syenogranite. Composed of quartz, microcline, oligoclase, 5–10 percent sodium-bearing hornblende and biotite, and accessory allanite, zircon, sphene, muscovite, and rutile. Quartz, microcline, and plagioclase form an interlocking matrix of anhedral grains with sparse phenocrysts of subhedral to euhedral microcline and smaller euhedral hornblende and biotite. Microcline contains inclusions of hornblende, rutile, biotite, quartz, and plagioclase and hornblende contains abundant inclusions of sphene. Subtle alignment of tabular microcline phenocrysts is locally present, but poorly developed and not visible in thin section (Burch, 1983). Rock is generally weathered to rounded exposures and forms a pink grus of variable thickness composed of angular quartz and feldspar grains. Alteration is common, with biotite replaced by magnetite, magnetite altered to hematite, and plagioclase altered to epidote and sericite. Extensive epidote alteration is present in Cow Creek area extending from contact with older metamorphic rocks north for approximately 2 km. This alteration is also present to west of map area in Sand Creek Pass quadrangle. Altered rocks form a prominent topographic high with much less grus development. Contacts with older intrusive and metamorphic rocks are generally sharp and are characterized by a breccia zone as much as 200 m wide cut by quartz and epidote veins. Small inclusions (less than 1 m in diameter) of older rocks are generally not found more than several meters from main intrusive contact. Due to greater erosional resistance of older granitic gneisses (Xfl) and granite porphyry (Yghp) intruded by Sherman Granite, contact frequently lies at base of a steep ridge and is consequently covered by an apron of colluvium derived from older metamorphic rocks on ridgeline. Eggler (1968) describes Sherman Granite as emplaced in sheet-like fashion based upon outcrop and gravity model evidence in other locations outside of map area. Apparent offsets along Sheep Creek fault zone imply that contact between Sherman Granite and older rocks to south dips to south-southeast below these older rocks and sub-parallel to structural grain in older rocks. Sherman Granite does not show evidence of solid state foliation, nor does it appear to deform foliation in older metamorphic rocks and truncates foliation and structural grain locally. Unit is cut by mafic dikes (Yd) within map area and by granite of Log Cabin batholith (YgLC) in southern part of Cherokee Park quadrangle (Eggler and Braddock, 1988) east of map area. Burch (1983) describes fine-grained, quartz-rich granite dikes as much as 4 m wide that cut unit near Eaton Reservoir, but lack of access to private lands prevented confirmation of existence and location of these dikes. U/Pb zircon age is 1,412±13 Ma (Alienikoff, 1983) and Rb-Sr isochron age is 1,430±20 Ma (Zielinski and others, 1981)

Porphyritic hornblende monzogranite (Mesoproterozoic?)—Tan to reddish-tan, fine-grained, xenomorphic, porphyritic hornblende monzogranite. Composed of fine-grained matrix of plagioclase, microcline, quartz, and minor amounts of hornblende and biotite with medium- to coarse-grained phenocrysts of predominantly quartz and hornblende and lesser amounts of microcline and plagioclase. Reddish color in some exposures comes from hematite alteration of hornblende and biotite. Forms an elongate tabular body exposed as a high ridgeline along Green Mountain and its continuation south of Sheep

Creek. Unit is cut by Sherman Granite (YgSH) and cuts older metamorphic rocks (Xfl and Xh). Maximum relative age is uncertain, but unit lacks foliation and cuts across structural grain of Paleoproterozoic rocks to east in Diamond Peak quadrangle (Braddock and others, 1989), so a Mesoproterozoic age is assumed

Granite of Rawah batholith (Paleoproterozoic)—Pink to gray, fine- to medium-grained, xenomorphic, inequigranular to equigranular, biotite granite. Composed of quartz, microcline (locally orthoclase present), plagioclase with magnetite, illmenite, biotite, and (or) hornblende generally present and accessory sphene, apatite, zircon, allanite, and, less commonly, sillimanite, rutile, and garnet. Secondary epidote or clinozoisite and muscovite are present along with clay alteration locally. Biotite percentage ranges significantly from absent to 7.5 percent and biotite-poor phases are generally not foliated. Unit contains abundant inclusions of older metamorphic rocks. Hornblende gneiss (Xh) inclusions are commonly rotated with foliations not parallel to regional wall-rock foliation and structural trends. Included bodies range from centimeter- to kilometer-scale in main body of Rawah batholith south of map area (Burch, 1983). Biotite schist (Xbq) inclusions are rarer and generally smaller. Inclusions of felsic gneiss may be common, but are difficult to recognize in field due to similar composition and texture. More geochemical work would be needed to clarify these relationships. Burch (1983) described biotite-rich foliated phases of Rawah batholith throughout its exposure in the Front Range. I have reinterpreted these foliated rocks as older felsic gneiss (Xfl) because their foliation parallels structure in other pre-Rawah metamorphic rocks, and because these rocks are quite similar to biotite granite gneisses that are interlayered with hornblende gneiss (Xh).

Northern boundary of Rawah batholith is defined by Cornelius Creek shear zone that is marked by 100–500 m wide zones of cataclastic deformation accompanied by extensive quartz veins and alteration. No mylonite fabric was observed within field area along structure. Brittle nature of this shear zone implies a post-Proterozoic age (Abbott, 1972). No Rawah granite is exposed to north of shear zone, so main intrusive contact between Rawah batholith and older metamorphic complex to north has been faulted out.

Rawah granite is intruded by granite of Log Cabin batholith (YgLC) in southeastern and south central parts of map area. In south-central part of map area (section 34 and 35, T. 11 N., R. 74 W.), unit is extensively intruded by pegmatite (YXp) and contains abundant centimeter- to meter-scale inclusions of metamorphic rocks (shown as pattern). Burch (1983) described these exposures as a porphyritic phase of Rawah granite, but it is more likely that this is a hybrid rock composed of older felsic gneiss (Xfl) inclusions (along with abundant hornblende gneiss (Xh) inclusions) partially assimilated by Rawah granite. This would explain abundance of pegmatite material. McCallum and Hedge (1976) report a whole-rock Rb/Sr age of 1,710 Ma. Correlative rocks south of map area along Cache la Poudre Canyon have a zircon age of 1,717±8 Ma (W. Premo, written commun., 2005)

Quartzofeldspathic biotite schist (Paleoproterozoic)—Includes interlayered biotite schist, biotite-hornblende felsic gneiss, biotite-sillimanite quartz schist, garnet-biotite felsic gneiss, and quartzofeldspathic granofels. Biotite schist is primary rock type. It is interlayered with felsic bands rich in plagioclase, microcline, and quartz. Garnet is common as poikioblasts in quartzofeldspathic layers, sillimanite occurs in association with biotite-rich layers, and magnetite is a common accessory mineral. Magnetite is responsible for dark red color in iron-rich soils developed on unit. Just north of Sheep Creek on eastern edge of map area, secondary copper mineralization (malachite) in unit is exposed in large abandoned mining pits and shafts. Biotite content is variable and unit grades from strongly foliated biotite schist to weakly foliated biotite felsic gneiss (Xfb). Compositional banding is largely migmatitic and parallels internal foliation defined by alignment of biotite. Banding forms isoclinal to tight folds with meter-scale amplitudes. Unit forms small, discontinuous lenses interlayered with felsic gneisses (Xfl and Xfb) and hornblende gneisses (Xh). Thin meter-scale layers are common throughout entire Paleoproterozoic metamorphic sequence, but unit is only shown where exposures dominated by biotite schist exceed approximately 15–20 m. Small (cm- to m-scale) rounded inclusions and larger (100 m-scale) inclusions elongate parallel to foliation are common within younger granite of Rawah batholith (XgR). Unit is interpreted as meta-sedimentary rock syndepositional with metavolcanic felsic (Xfl and Xfb) and mafic (Xh) gneisses and therefore of similar depositional age. Peterman and others (1968) define regional metamorphic age from whole-rock Rb/Sr ages that have been recalculated by Braddock and others (1989) to 1,713±30 Ma. This corresponds to peak metamorphism driven by heat from emplacement of Rawah batholith

Leucocratic felsic gneiss (Paleoproterozoic)—Pink to red, fine-grained, leucocratic felsic gneiss. Composed of quartz, plagioclase, and microcline with less than 5 percent biotite and (or) hornblende and magnetite. Composition ranges significantly from aplitic rocks lacking any visible dark minerals to granitic gneiss containing significant hornblende (Xh) or biotite (Xfb). Unit defined by greater than 50 percent leucocratic felsic gneiss where interlayered at centimeter- to meter-scale with hornblende gneiss and amphibolite (Xh), biotite felsic gneiss (Xfb), or quartzofeldspathic biotite schist (Xbq). Foliation defined by interlayering with other units, by fine-scale compositional layering, by alignment of fine-grained biotite or hornblende crystals, and by elongated medium-grained porphyroblastic augen aggregates composed of intergrown fine-grained quartz and feldspar. Foliation is generally poorly defined and absent in more felsic, massive exposures. Strongly layered exposures are interpreted as felsic portion of a Paleoproterozoic volcanic sequence that was strongly metamorphosed and foliated prior to intrusion of Rawah batholith (XgR). Zircon ages from SHRIMP analysis of a sample collected east of map area along Cherokee Park road indicate an age of primary volcanism at 1,766.6±8.3 Ma (W. Premo, written commun., 2006). Broad expanses that lack interlayered biotite or hornblende gneisses (for example, between Acme Creek and Beaver Creek on Hill 8765, section 11 and 14, T. 11 N., R. 74 W.) may represent either intrusive bodies or thick felsic volcanic masses, but these exposures grade seamlessly into more layered sequences and their foliations are subparallel. Further subdivision of this unit would require more detailed study and current usage represents a field term for rocks of a consistent composition, texture, and metamorphic age

Biotite felsic gneiss (Paleoproterozoic)—Black to pinkish-gray to red, fine- to medium-grained biotite felsic gneiss. Composed of quartz, plagioclase, and microcline with as much as 10 percent or greater biotite and (or) hornblende and magnetite. Garnet is rare as poikioblasts. Foliation defined by fine- to medium-grained biotite or hornblende crystals aligned within seams anastomosing around elongated medium-grained microcline augen or aggregates composed of intergrown fine-grained quartz and feldspar. Unit is compositionally intermediate between quartzofeldspathic biotite schist (Xbq) and leucocratic felsic gneiss (Xfl) and occurs as small meter-scale layers within both units; interpreted as intermediate composition metavolcanic rock. Unit is only mapped separately along core of an antiform offset by the Sheep Creek fault zone in east-central part of map area. Southwest of Sheep Creek, unit is exposed as a 200-m-wide band of biotite-rich felsic gneiss that grades to the west into felsic gneiss (Xfl) as biotite content decreases. Northeast of Sheep Creek unit forms a 100-m-wide band that grades north, south, and east into biotite schist (Xbq) as biotite content increases. Zircon ages from SHRIMP analysis of a sample collected along Devils Creek to east of map area indicate an age of primary volcanism at 1,775.5±4.0 Ma (W. Premo, written commun., 2006)

Hornblende gneiss and amphibolite (Paleoproterozoic)—Dark gray to black, fine- to coarse-grained, interlayered hornblende gneiss, amphibolite, and biotite-hornblende gneiss. Composed predominantly of hornblende with variable proportions of plagioclase and minor quartz and biotite and (or) magnetite, and rarer orthoclase; interpreted as mafic composition metavolcanic rock. Unit is interlayered with felsic and biotite gneisses and locally grades into felsic gneiss (Xfl) as hornblende content decreases. Map unit defined by greater than 50 percent hornblende gneiss or amphibolite where interlayered at centimeter- to meter-scale with leucocratic felsic gneiss (Xfl), biotite felsic gneiss (Xfb), and quartzofeldspathic biotite schist (Xbq). Lenses of calc-silicate gneiss and localized light to dark green alteration bands of epidote- or chlorite-bearing rocks are common. Massive, coarse-grained, strongly magnetic amphibolite layers completely lacking plagioclase and commonly rich in garnet form resistant ridges 50–200 meters wide and several kilometers long that parallel surrounding foliations and structural grain. These layers may represent small metagabbro intrusive bodies, thick mafic to ultramafic volcanic masses, or concentrations of more competent rock along hinges of large-scale tight folds (for example, ridge extending southwest from Hill 8890, section 18, T. 11 N., R. 75 W.). These exposures grade seamlessly into layered more plagioclase-rich sequences and no intrusive contacts were observed, although exposure is generally poor. Further subdivision of this unit would require more detailed study and current usage represents a field term for rocks of consistent metamorphic age rich in hornblende. Magnetite-rich outcrops have been mined in numerous locations, most notably along north side of George Creek.

Foliation in unit defined both by interlayering with other units, compositional layering, and alignment of elongate, prismatic hornblende crystals within a matrix of subhedral to euhedral plagioclase. Poikioblasts of hornblende contain small inclusions of opaque minerals, sphene, biotite, and epidote that parallel foliation. Less commonly, poikioblasts of plagioclase contain inclusions of zircon, sphene, and hornblende forming a spotted amphibolite texture. Quartz and orthoclase occur as minor phases within matrix of rock between larger hornblende and plagioclase crystals. Plagioclase-poor and plagioclase-rich compositional layers at scale of 1–10 cm are common and define bands that outline tight recumbent folds with centimeter- to meter-scale amplitudes. Adjacent to faults, unit generally shows strong lineation parallel to fault plane. Rocks of this unit are common as inclusions throughout younger granite of Rawah batholith (XgR) and as small inclusions along contact zone with younger Sherman Granite (YgSH). Foliation and compositional layering are cut by younger Rawah granite (XgR). Zircon ages from SHRIMP analysis of a hornblende-rich sample collected west of Beaver Creek along Forest Service Road 169 (northwest corner of section 22, T. 11 N., R. 74 W.) indicate an age of primary volcanism at 1,779±5 Ma (W. Premo, written commun., 2007)

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Contact—Dashed where approximately located

Fault—Bar and ball on downthrown side. Dashed where approximately located; dotted where concealed

Fault zone—Characterized by brittle deformation in most locations with a variety of lithologies present as millimeter- to meter-scale clasts within fault breccia and cataclastic material; alteration is common; quartz veins are common. Solid where boundaries of deformation certain; dashed where approximately located; dotted where concealed

Areas in which abundant pegmatite dikes (YXp) pervasively intrude older granite of Rawah batholith (Paleoproterozoic)

Antiform—Dashed where approximately located

Synform

Overturned antiform

Overturned synform

Inclined foliation in metamorphic rocks—Showing strike and dip

Vertical foliation in metamorphic rocks—Showing strike

Lineation—Showing bearing and plunge

Minor fault or shear plane—Showing strike and dip