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The Tobacco Root Geological Society

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ABSTRACTS

GEOLOGY OF SOUTHERNMOST RAVALLI COUNTY, MONTANA

by

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In southernmost Ravalli County, greenschist facies quartzite of Precambrian age is separated from a sequence of biotite-quartz-feldspar gneiss, amphibolite, and augen gneiss by a low-angle fault. The quartzite section, which is inferred to be 25,000 ft (7.6 km) thick, consists of three lithologic units, which are distinguished by differences in grain size and by the relative abundance of quartz, K-feldspar, and albite. These units have not been correlated with units of the Belt Supergroup, but are lithologically similar to quartzite units of Precambrian Y age in east-central Idaho. Quartzite schist, also of Precambrian age, is in fault contact with the quartzite units. Metagabbro dikes and sills occur both in the quartzite and in the quartzitic schist. A large body of metagabbro and a body of augen gneiss are exposed in contact with the quartzitic schist in the area west of the West Fork.

The precursor of the biotite-quartz-feldspar gneiss is unknown, but arkosic units in the sequence of Precambrian quartzite units are a likely possibility. The augen gneiss is an orthogneiss of granitic composition. Although some rock recognized as metagabbro occurs within the area mapped as amphibolite, an igneous origin for all of the amphibolite can only be inferred.

High-angle faults that trend north are prominent along the West Fork of the Bitterroot River. A distinctive-schorl-bearing protomylonite occurs along some of the faults within the quartzite as well as along some faults between the quartzite and other units.

Felsic dikes, clearly post-metamorphic, are found throughout the area but are most abundant in quartzite in the vicinity of the West Fork. Remnants of Tertiary welded tuff, flows, and bedded tuff, which range in composition from rhyolite to basalt, are exposed in two areas of intermediate to high altitude. The distribution of these volcanic units indicates the partial filling of tributary gulches with volcanic material. Irishman's Rock, a prominent knob along the Idaho-Montana border near the head of Mine Creek, is a basalt plug.

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GEOTHERMAL INVESTIGATIONS IN SOUTHWESTERN MONTANA: STATUS REPORT

by

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and

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Twenty-five hot springs in southwestern Montana are being examined, with the cooperation and support of the U.S. Geological Survey, to improve understanding of thermal-water migration and to provide a preliminary assessment of the geothermal potential of the region. The study entails geologic and structural mapping, hydrologic measurements, measurements of geothermal gradients in wells, chemical analyses of water, and shallow resistivity and seismic surveys.

Most springs issue from fractured igneous or metamorphic rocks or from valley-fill sediments within or marginal to fault-block valleys. Some springs are located at structural intersections such as faults or shears with open-joint systems (Potosi, Alhambra) or faults with faults (LaDuke, Chico, Renova, Wolf Creek). Other springs (for example, Bozeman, Hunters, New Biltmore, Norris) are located along known or inferred faults, but any cross-structures are obscure. Resistivity lows 10-40 m deep at Bozeman, Wolf Creek, Alhambra, and White Sulphur Springs may delineate fractures serving as conduits for the thermal water.

Calculations based on chemical geothermometers suggest that reservoir temperatures range from about 55° to 140° C. Observations from deep wells and mines, limited stable-isotope studies, and lack of post-Miocene igneous activity except near the southern border of the State suggest that deep circulation of meteoric water is a major source of heat. If shallow reservoirs can be located and tapped, the thermal waters may be utilized for space heating, greenhouse crop production, or electric power generation using heat-exchange systems.

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DEPOSITIONAL HISTORY OF THE YELLOWSTONE "FOSSIL FOREST"

by

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and

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Recent work on the paleoecology of the Yellowstone "Fossil Forest" and reconnaissance observations of the sedimentary features of the emtombing volcaniclastic sediments suggest the need for modifying previous interpretations of the depositional environment. Classically the fossil "forests" have been interpreted as the preserved remains of living forests buried in situ by subaerial lahars (volcanic mud-flows) and air-fall ash. The possibility of subaqueous deposition has been de-emphasized since the original interpretations of Holmes (1878, 1879) that the sediments were lacustrine deposits. Our results, although still preliminary, have re-emphasized the need for water transport and mixing to explain the heterogeneous flora and both moving and standing water to explain such obvious subaqueous sedimentary structures as cut-and-fill, low angle cross-bedding, flamestructures, load casts, fine parallel lamination (including draped lamination), and graded bedding (normal, reverse, and symmetrical).

We suggest the following depositional model as the most satisfactory interpretation consistent with all presently available information, recognizing that much additional work must be done to either confirm or refute it. The depositional setting envisioned is a prominent northwest-southeast trending intermontane basin flanked by subparallel chains of active andesitic strato-volcanoes. The actual basin of deposition was a broad alluvial plain of low relief with streams flowing into a large freshwater lake. The flood plain and subaqueous delta system of the lake were spasmodically receiving catastrophic influxes of volcanic mud-flows and ash-flows supplied by nearby erupting vents. Torrential rainfalls may have remobilized into stream floods the volcanic debris deposited on the volcanoes flanks or alternately vent breccias may be involved, some of which may have been both erupted and emplaced underwater.

Simultaneous to the rapid accumulation of volcaniclastic sediments plant parts (leaves, cones, pollen and spores, logs, and stumps) were being transported to the depositional site and after becoming waterlogged settled out in slack-water areas where they were entombed by debris flows of volcanic breccias, conglomerates, and ash or by pyroclastic ash settling in water. This model includes at least some of the upright stumps which then do not represent trees buried in situ. The closest modern analog for the type of volcanic sedimentation and plant burial we are suggesting is the region surrounding Volcan Fuego and neighboring active volcanoes of Guatemala where interestingly the combined montane and lowland flora is quite similar to that preserved in the Yellowstone "Fossil Forest."

Further study will undoubtedly provide a clearer picture of the depositional history now evolving and future investigators should keep an open mind to changing interpretations based on additional field and laboratory findings.

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PALEOECOLOGY OF THE YELLOWSTONE "FOSSIL FOREST"

by

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and

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One of the most magnificent of all Tertiary paleobotanical localities is the multiple layered "Fossil Forest" of Yellowstone National Park. These "forests" are Middle Eocene in age and belong the the Lamar River and Sepulcher Formations of the Absaroka Volcanic Supergroup. The large number of well-preserved vertical stumps and horizontal logs along with other plant remains such as leaves, cones, pollen, and spores, provides an excellent opportunity to study the paleoecology of the "forests" in detail.

Since the initial paleobotanical investigations of about 100 years ago (Lesquereux, 1872; Holmes, 1878; Knowlton, 1899) a mixture of plant types representing cool temperate to tropical taxa has been reported. Identified were such temperate taxa as Acer (maple), Betula (birch), Carya (hickory), Fagus (beech), Sequoia (redwood), and Ulmus (elm), along with numerous warm temperate to subtropical broad leaf types and a few tropical taxa such as Artocarpus (breadfruit), magnolias, laurels, and aralias. This range of climatic indicators is common for transported Paleogene floras, but seemed a little strange if the "forests" were preserved in situ. Subsequent work on the wood (Conard, 1930; Read, 1930; Beyer, 1954; Wheeler and Barghoorn, 1976) and leaves (Dorf, 1960, 1964) has confirmed the presence of Terminalia (white mangrove), Ficus (fig), and Persea (avocado) along with more temperate indicators including Abies (fir) and Picea (spruce). Detailed stratigraphic work on the palynology of the fossil "forests" by Fisk (1976) and DeBord (1977) has added several additional taxa to the flora and revealed that the heterogeneous mixture may be present in the palynoflora of individual "forests." New taxa reported from the pollen included Ephedra (mormon tea), Podocarpus, Taxus (yew), Nyssa (water tupelo), ? Rhizophora (red mangrove), and Tilia (linden).

The mixture of climatic types seen in the pollen and leaves has been explained by transportation of montane floral elements into the subtropical valleys of deposition caused by rain showers and flooding associated with volcanic eruptions. Thus, the mixture should in no way involve the actual trees of the "forests." However, recent work on the stumps and logs from a single depositional unit on the Amethyst Mountain "Fossil Forest" by Fritz (1977) has revealed that the mixture is also present in the vertical stumps of this one "forest." Identified were such taxa as Picea (spruce), Pinus (pine), Sequoia (redwood), Podocarpu, Aralia, and Artocarpus (breadfruit).

In summary, like other Paleogene fossil floras the fossil "forests" of Yellowstone National Park contain an admixture of plant remains representing climates ranging from cool temperate to tropical. If we assume that the fossil plants had ecological tolerances similar to their living counterparts then considerable transport of various plant parts seems necessary to explain the heterogeneous assemblage.

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SANDY HOLLOW COLLISION STRUCTURE

by

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and

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The Sandy Hollow collision structure is a décollement in the gastropod limestone member of the Kootenai Formation (Cretaceous) produced by impingement of the upper plate of the Laramide Sandy Hollow thrust fault on the more or less stationary nose and eastern limb of the Sandy Hollow anticline. At the (exposed) point of impact the upper 33 meters of the 40 meter-thick gastropod limestone are torn loose from the basal unit and are thrown into a series of tight, eastward verging similar folds and thrust faults. Southeastward away from the impingement point the folds become open flexural slip folds in competent limestone units. Effects of the collision die out completely at a distance of 450 meters from the point of impact.

A more or less uniform strain gradient exists in the collision structure, with highest strain occurring at the point of impact. Strain is measured by fold shape, density of cleavage, fold type, and calcite twinning. A series of late thrust faults interrupt the folds of the collision structure and cause local strain and slight reorientation of the folds. Analysis of these faults and folds shows that the collision structure was produced rapidly at shallow depth by a more or less uniform stress field in which σ_1 (greatest principal stress axis) was oriented N80°W - S80°E.

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GEOLOGY OF THE SKAGIT QUEEN CLAIMS, NORTH CASCADE RANGE, WASHINGTON

by

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The Skagit Queen claims are a group of 36 patented claims situated 12 miles south of Diablo Lake in northwestern Washington. The claims are located in Pre-Upper-Jurassic orthogneiss and paragneiss of intermediate composition, a few miles northeast of the Cascade Pass quartz diorite stock which is dated at 20 m.y. The gneiss strikes NNW and dips about 45°W. The claims are staked along 10 to 20 foot wide shear zones that strike north to northeast and dip at high angles to the west and are part of the Buckindy transverse structural belt.

In places the shear zones widen enormously into bulbous structures which constitute the ore bodies for these claims. Quartz sulfide veins containing high-grade silver, gold, and base metal ore are developed within the bulbous structures. In addition to the veins and hydrothermally altered gneiss, the ore bodies contain diabase and andesite dikes that intruded the shear zones penecontemporaneously with the mineralization. The veins, which are largely a product of open space filling, vary in width from one inch to 3.5 feet and contain pyrite, galena, sphalerite, chalcopyrite, acanthite, and gold as ore minerals with quartz, siderite, calcite, anhydrite, and barite as gangue. Wallrock alteration in the ore bodies is characterized by propylitic alteration away from the veins and sericitic alteration adjacent to the veins.

The geologic history of the Skagit Queen claims can be summarized as follows: (1) deposition of arkosic sediments followed by intrusion of quartz diorite; (2) metamorphism of the sedimentary and igneous rocks into garnet-bearing gneisses with attendant deformation, uplift, and subsequent retrograde metamorphism; and (3) development of shear zones in the country rocks followed by intrusion of the Cascade Pass Stock, mafic dikes, and mineralization along the shear zones.

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IDENTIFICATION OF TERTIARY SEDIMENTARY BASINS UNDER THE NORTHERN AND EASTERN MARGINS OF THE COLUMBIA BASALT PLATEAU

by

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and

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Until recently, the Tertiary rock column along the northern and eastern margins of the Columbia Basalt Plateau was considered to comprise primarily massive basalt flows with fractured and weathered flow tops and thin sedimentary interbeds. The flows typically have thicknesses in the 100 ft (30 m) range while the sedimentary interbeds may be 10 ft (3 m) or less. The sediments are derived from Precambrian Belt Group metasediments, Idaho Batholith-type rocks, and the basalt flows.

Geophysical well logs, gravity and magnetic surveys, and electrical resistivity soundings indicate that along the margins of the Plateau, some sedimentary interbeds may be as thick as 500 ft (150). The gravimetric method is the best geophysical technique for outlining these abnormally thick interbeds.

Initially, gravity interpretation models for the northeastern margins of the Plateau assumed that the areas of greatest basalt accumulation would exhibit high gravity responses relative to thinner accumulations of basalt and pre-basalt basement outcrop. However, two methods can be used to indicate that the density of the Tertiary rock column is equal to or less than the density of the basement rocks. Where thick sediment accumulations occur, the total density of the Tertiary rock column is even lower and thus these areas are readily outlined on a gravity map.

The area in the vicinity of Davenport-Reardan-Cheney, Washington overlies a low in the gravity anomaly which is interpreted to be a sedimentary basin obscurred by surface basalts. Reconnaissance gravity data are integrated with well logs and surface geology to strengthen the case.

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ABSTRACTS

AGE, STRATIGRAPHY, AND DEPOSITIONAL HISTORY OF TERTIARY ROCKS NEAR PILOT ROCK, NORTHEASTERN OREGON

by

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and

Lanny H. Fisk[1]

Tertiary sedimentary rocks outcropping along East Birch Creek and its tributaries, southeast of Pilot Rock, Umatilla County, Oregon, have consistently been mapped as Clarno Formation and assigned an early to middle Eocene age. Our study of both the mega- and microflora and comparison with other Tertiary floras in the Pacific Northwest suggests that rocks of two different ages are represented, one Paleocene-Eocene and the other Miocene.

The older stratigraphic sequence of carbonaceous shales and mudstones, arkosic sandstones, and thin coals is lithologically distinct from the type Clarno Formation and closely resembles rocks of the Paleocene Swauk and Chuckanut Formations of northwestern Washington.The flora is also comparable between these formations suggesting a similarity in age. A similar sedimentary sequence found on Arbuckle Mountain southwest of the Pilot Rock area has recently been informally proposed as a new stratigraphic unit, the "Herren Formation." We suggest that the depositional environment for all these rocks was coastal alluvial plain to deltaic.

Also represented in the East Birch Creek area is a thick interbed in the Miocene Columbia River Basalts. Outcrops of tuffaceous shales and siltstones along Pearson Creek yield typical Miocene leaves and a palynoflora identical to other Coriba interbeds. This sequence represents an accumulation of volcanic ash sedimented into a temporary and short-lived lake.

Although the stratigraphy is complex, we believe that this study has clarified and hopefully put to rest the controversy over the age relationships of the sedimentary, leaf-bearing rocks in the Pilot Rock area.

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PALEOECOLOGY AND DEPOSITIONAL HISTORY OF THE MIOCENE LATAH FORMATION, SPOKANE, WASHINGTON

by

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Sedimentary interbeds in the Miocene Columbia River Basalts in the vicinity of Spokane, Washington, have been referred to a separate stratigraphic unit, the Latah Formation, even though they may not be coeval and in some cases are separated by several individual basalt flows. The interbeds are typically composed of carbonaceous and micaceous sandstones, siltstones, and shales which yield an excellently preserved fossil flora. Included in the megafossils are such taxa as *Sequoia*, *Taxodium*, *Acer*, *Alnus*, *Castanea*, *Quercus*, *Liquidambar*, *Laurus*, *Cercis*, *Magnolia*, and *Platanus*. Study of the palynoflora has further documented most of the above plus added several new records for the Latah Flora including *Osmunda*, *Picea*, *Ilex*, *Juglans*, *Pterocarya*, and *Reevesia*. The more complete flora analysis provided by both mega- and microfossils indicates that the paleoclimate during "Latah time" was probably warm temperate in the lowlands and slightly cooler in the nearby highlands, the inferred source of cooler climatic indicators such as pollen of *Abies*, *Larix*, *Picea*, and *Tsuga*.

The Latah sediments are interpreted to have accumulated in temporary, shallow lakes probably formed through the damming of streams by lava flows. Aquatic plants, diatoms, the alga *Pediastrum* , and several types of dinoflagellates support this interpretation, as does the presence of frequent pillow basalts. The continued presence of bottom currents in the shallow lakes is indicated within the lacustrine sequence by thin, cross-bedded, channel sandstones. Both sedimentological and paleontological features indicate relatively rapid accumulation of clastic and tuffaceous sediments resulting in infilling of the lakes with fairly quick succession.

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PETROLEUM POTENTIAL OF TERTIARY STRATA IN NORTHEASTERN OREGON

by

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The Cenozoic stratigraphic section in Morrow and Umatilla Counties, northeastern Oregon, contains about two thousand feet of Tertiary nonmarine sedimentary rocks which have been preliminarily evaluated for petroleum potential. Recent study of the age, stratigraphy, paleoecology, and depositional history of this sequence has revealed the presence of possible source and reservoir rocks in strata previously incorrectly mapped as Clarno Formation. As the Clarno is principally volcanic, the petroleum potential of these pre-Clarno rocks has been thus far unsuspected and untested. The strata are as yet unnamed but informally referred to as the "Herren Formation." Based on floral composition these rocks are probably Paleocene to early Eocene in age.

The sedimentary sequence of the "Herren Formation" consists of moderately indurated, dark-gray to black, organic-rich shales and siltstones which locally contain an abundance of recognizable terrestrial and aquatic plant fragments and some thin coals. Associated with these potential source rocks are relatively clean quartzo-feldspathic sandstones which are in part carbonaceous and calcareous. Sandstone bodies are composed of relatively coarse, well-sorted, and cross-bedded channel sands. The sequence was apparently deposited in environments ranging from alluvial fan to marginal deltaic on a low broad coastal plain.

Source-rock analyses indicate that rocks from this sequence contain up to 70% organic carbon which ranges in thermal maturity from immature to mature, evaluated from the study of palynomorph color. Carbonaceous shales contain extractable saturated hydrocarbons detectable by ultraviolet fluorescence. Sandstone porosities and permeabilities appear low but suggest the presence of possible reservoir beds. The potential reservoir sandstones occur as stacked sequences ranging in thickness from about 2 m to more than 20 m. Both structural and stratigraphic traps could account for commercially exploitable hydrocarbon accumulations. Overlying basalts of this Miocene Columbia River Group could provide a seal for migrated or late generated hydrocarbons.

From preliminary analysis of the Tertiary sequence in outcrop, it is fair to conclude that rocks of the "Herren Formation" constitute a significant potential petroleum source-rock assemblage which would appear to warrant comprehensive appraisal including seismic exploration and a wildcat drilling program. Extensive surface studies are needed to delineate the most prospective subsurface exploratory targets. The presence of extractable petroleum in shale samples and the discovery of a large dry natural gas accumulation in a recently drilled water well should provide further impetus to exploration.

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THE ORIGIN OF ARCHEAN QUARTZO-FELDSPATHIC GNEISSES IN THE BEARTOOTH MOUNTAINS, MONTANA AND WYOMING

by

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and

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Quartzo-feldspathic metamorphic rocks, usually mapped as granitic and tonalitic gneiss, are the most abundant Archean rock types in the Beartooth Mountains of Montana and Wyoming. Hypotheses presented for the origin of these gneisses include metamorphism of sequences of sedimentary and volcanic rocks of the appropriate composition, anatexis of pre-existing rocks, metasomatism of intrusive rocks. Analysis of available chemical data indicates that the gneiss protoliths were calc-alkaline igneous rocks similar to those formed in Phanerozoic Andean margins. A strong negative correlation between TiO_2 and SiO_2 contents of the gneisses follows similar trends observed for calc-alkaline plutons and is distinctly different than trends reported for metamorphosed quartz-feldspar rich sandstones. Silica contents in the gneisses range from 55 to 76%, $FeO + Fe_2O_3/MgO$ ratios exceed 2.0 and Ba/Sr ratios are greater than 1.0. Similar chemical variations are observed in calc-alkaline plutons associated with Andean margins where ocean crust is subducted under continental crust. Limited published isotope data support the interpretation that the gneisses were originally juvenile granitic, granodioritic and tonalitic magmas generated in the mantle, added to the early crust and metamorphosed prior to 3.0 b.y. BP. Smaller discordant granitic bodies (e.g. the Mouat quartz monzonite, the Crevice Mountain granite) and the Stillwater Complex intruded the metamorphosed, deformed gneisses 2.7 b.y. BP. The granitic bodies are essentially undeformed and exhibit only low grade metamorphism. Published isotope data indicate that continental crustal rocks participated in the generation of the later magmas. Thus, there is a two-fold igneous sequence in the development of the early continental crust in the Beartooth Mountains. The earliest magmas were apparently generated from rocks of mantle composition and the later magmas involved continental crust. This mode of Archean crustal evolution differs from models invoking growth of the Archean crust by magmatic additions from the mantle only.

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GLACIAL GEOLOGY OF CATARACT CREEK AND NORTH WILLOW CREEK VALLEYS, TOBACCO ROOT RANGE, MONTANA

by

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and

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The Cataract Creek and North Willow Creek Valleys head a complex of cirques immediately east of the crest of the Tobacco Root Range near Mt. Hollowtop. The valleys trend northeast and merge about 2.5 km west of Pony. The junction marks the approximate limit of downvalley ice advance in both valleys. This area contains moraines, rock glaciers, and mass wasted deposits that record Pinedale and Neoglacial events.

Both valleys are characterized by prominent lateral moraines along their northwestern side. In places these moraines include a series of subparallel ridges representing the accumulation of several advances An analysis of geomorphic characteristics, clast weathering, and soils (soil morphology, particle size, clay mineralogy, heavy minerals, and geochemistry) of these lower valley moraines indicate an early Pinedale age and that the several advances are not separated by enough time to significantly affect weathering characteristics.

Both valley systems also contain younger moraines at higher elevations encircling Mason Lake and Hollowtop Lake only 0.9 km and 2.0 km, respectively, from the cirque headwalls. These deposits have the geomorphic and weathering characteristics typical of the late Pinedale glaciation of the Tobacco Root Range. In some respects weathering has progressed more here than in the older deposits downvalley because of a greater amount of precipitation at higher elevations.

Within the cirques are multiple levels of rock glaciers, protalus ramparts, and talus lobes and fans. Only at Upper Mason Lake has a probable moraine been found rimming the cirque, which may represent the only record of a post-Pinedale ice advance in this area. Geomorphic and weathering characteristics indicate that the cirque deposits largely reflect periods of periglacial activity corresponding with the early Neoglacial, Audubon, and Gannett Peak ice advances elsewhere in the Rocky Mountains.

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IDAHO BATHOLITH GEOLOGY AND GOLD MINERALIZATION AT FLORENCE, IDAHO

by

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The Florence mining district is located five miles north of the Salmon River in southern Idaho County, Idaho. Florence is famous for its fabulously rich placer ground which yielded about 1.5 million ounces of gold during the 1860's. Hardrock gold production has been comparatively small and is estimated at 10,000 ounces.

Bedrock of the mineralized area is biotite quartz diorite of the Bitterroot lobe of the Idaho batholith. Sodic andesine, quartz and biotite comprise 95 - 99 percent of the quartz diorite. The quartz diorite often has a weak schistosity in outcrop. Southeast of Florence the batholith is vertically zoned with quartz diorite on top and granodiorite and quartz monzonite at depth.

West of Florence the quartz diorite is in contact with pre-Jurassic metamorphic rocks. Here the quartz diorite contains hornblende with inclusions of plagioclase, biotite, quartz, sphene, epidote, and chlorite. The hornblende apparently formed due to reaction between quartz diorite magma and the metamorphic rocks. Metamorphic rocks exposed at the bottom of the Salmon River canyon southeast of Florence possibly represent the approximate lower contact of the batholith. The thickness of the batholith between the metamorphic rocks here and those west of Florence is about 4000 feet. Alternatively, the lower metamorphic rocks could be a gigantic sunken xenolith. During intrusion of the batholith there was lit-par-lit injection of the magma into the metasediments and incorporation of xenoliths of various sizes, shapes, and orientations into the batholith. The original schistosity of the metamorphic rocks along the Salmon River batholith contact is preserved.

Granite, granodiorite, aplite, and pegmatite dikes cut the batholith. These dikes probably are fractional crystallization products of the batholith. A granodiorite porphyry dike which cuts an aplite dike, and a quartz diorite dike are possibly related to an igneous event that postdates crystallization of the batholith. The gold veins cut all the aforementioned dikes. A three foot wide olivine basalt dike northwest of Florence is probably related to some Columbia River basalt outcrops (erosional remnants) 2.5 miles to the west.

Most of the veins at Florence occur in a northeast trending area of about 8 square miles. Three sets of veins are recognized in Florence:an E-W set, a NE set, and a NW set. Nearly all the veins dip south at moderate to high angles. The E-W veins are the most common and NW veins the least common.

The veins show different degrees of development, ranging from narrow seams of hydrothermally altered quartz diorite one-eighth inch wide to sheeted zones of veins totaling 40 feet in width. The individual veins in the sheeted zones are typically 2 - 4 inches wide. The widest single quartz vein visible is one foot wide. The size of the ore shoots in single veins is a function of the amount and direction of movement along the fracture as well as the wavelength, amplitude, and frequency of the fracture curvature. All the veins show small lateral movement and open space filling is the dominant vein forming mechanism.

Sericitic wall-rock alteration accompanies the veins. Plagioclase and biotite are replaced by sericite but quartz is unaltered K-feldspar is replaced by sericite and quartz at high elevations but is unaltered at depth.

Gold and silver are the elements of economic importance found in the veins. Gold and acanthite (Ag_2S) formed late in the mineralization after at least two periods of fracturing and deposition of the quartz. Scattered pyrite and base metal sulfides are associated with the gold and acanthite.

Two hypotheses for the origin of the Florence gold veins are as follows: (1) the veins are a product of fractional crystallization of the Idaho batholith and (2) the veins developed from a separate mineralization event unrelated to the batholith. The fact that gold is depleted during the fractional crystallization of igneous rocks weighs heavily against this mechanism for the origin of the gold veins Structural and mineralogical features of the veins at Florence and other central Idaho gold mining districts suggest the mineralization in these districts is due to a separate event, possibly related to emplacement of porphyry type mineralizaton.

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HYDROGEOLOGY OF THE MILLIGAN CANYON AREA, MONTANA

by

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The Milligan Canyon area, located approximately 16 km. northwest (10 miles) of Three Forks, Montana, consists of a broad plunging synclinal basin which trends southwest to northeast and covers 130 sq. km. (50 sq. miles). Mississippian age Madison Group carbonates and other pre-Tertiary formations are folded, faulted and overlain by flat-lying Tertiary and Quaternary sediments. The study was conducted to examine the ground-water chemistry, artesian flow and orientation of fracture traces that may influence flow in the basin.

Water levels and samples were taken from existing wells and springs. Samples were analyzed for SpC, pH, C^{2+}, Mg^{2+}, Na^{+}, K^{+}, HCO^{-}, Cl^{-}, SO_4^{2-}, NO_3^{-}, Li^{+}, F^{-}, total iron and total manganese. A piezometric map constructed from the water levels shows eastward ground-water flow. Four prevalent water chemistries exist along the flow path: calcium-bicarbonate, calcium-sulfate, sodium-sulfate and sodium-bicarbonate. The recharge areas near structural highs have calcium-bicarbonate waters that evolve to calcium-sulfate waters downgradient possibly due to contact with evaporite sequences. Further along the flow path sodium dominates over calcium possibly due to cation exchange in Tertiary clays derived from Cretaceous volcanics. Dilution of the sodium-sulfate waters by calcium-bicarbonate waters from the Elkhorn Mountains Volcanics creates a sodium-bicarbonate water in the eastern part of the basin.

Fracture trace analysis was utilitzed to locate the surface expression of concentrated fracture zones which may provide avenues for artesian Madison waters to seep into overlying rocks. The distribution of the azimuthal directions of fracture traces and joints from pre-Tertiary formations were compared and both groups show a similar general trend of north-south and east-west sets.

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AN ANALYSIS OF JOINTING IN FOLDED AND FAULTED SEDIMENTARY ROCKS OF THE NORTHERN TOBACCO ROOT MOUNTAINS: A COMPUTER IMPLEMENTED STUDY

by

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and

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Joint readings were taken in five separate areas of folding and faulting in the flanking Paleozoic and Mesozoic sedimentary rocks of the northern Tobacco Root Mountains, Madison County, Montana. In each area two different types of joints were recognized. The statistically dominant fractures for all areas are ac or bc joints whose attitudes rotate with bedding around the hinges of the folds. A second group of joints maintain a fairly constant attitude across a fold, and defines a single or double set of surfaces which strike at a moderate angle to the fold axial trace and associated faults.

The first group of joints are interpreted as tension joints formed parallel to the local $\sigma_1 - \sigma_2$ stress plane in the evolving fold. As the stress axes rotated across the fold hinge so did the attitude of the tension joints, particularly the bc joints. The second group of joints - here called "oblique" joints - are interpreted to be conjugate shear surfaces related to the external stress field affecting the folds and faults late in the period of deformation. Stress axes inferred from oblique joints agree well with stresses derived from other indicators or fold geometry, fault plane attitudes, and slip vectors along faults.

To facilitate the display and analysis of joints, the authors have developed computer-generated programs to plot and contour joint pole data on spherical, stereo-pair equal area diagrams which can be viewed from any desired angle.

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GLACIAL GEOLOGY AND SOIL GEOMORPHOLOGY OF ALPINE TILLS IN THE SOUTH BOULDER RIVER VALLEY, TOBACCO ROOT RANGE, MONTANA

by

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and

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A study of the sequence of glacial moraines in the South Boulder River Valley has yielded information concerning the nature of soil development in alpine glacial tills. Bull Lake tills are farthest downvalley and have the greatest soil development. Post-Bull Lake soils are cryobollols with surface base saturations exceeding 70%. These soils have moderately well developed argillic horizons and clay enrichments of 7 to 10%. B horizons have 7.5 YR Munsell colors, medium subangular blocky soil structure and weak clay skins on ped faces. The sites studied yielded free iron oxide enrichments of about 1% and the lowest hornblende/zircon + tourmaline and illite/expandables ratios in the surface horizons.

Pinedale moraines are represented by a sequence of tills upvalley from older deposits but below the cirque area. These deposits have been interpreted as the result of at least three major advances of Pinedale ice. Several Pinedale moraines were influenced by great post-depositional erosion and loess deposition. Post-Pinedale soils are quite diverse. These soils are mollisols, transitional mollisols-alfisols, and alfisols. Clay enrichments range from 2 to 8%, and solum thicknesses from 30 to 50 cm. In general, Post-Pinedale soils have cambic horizons with weak subangular blocky to single grain soil structure and 10 YR Munsell soil colors. Little or no free iron oxide enrichment was detected. Upvalley, there is a general trend of decreasing base saturation of surface horizons as well as an increase in illite/expandables and hornblende/zircon + tourmaline ratios.

The Holocene is represented by Gannett Peak and Audubon deposits. The Post-Neoglacial soils are entisols with clay enrichment of 3% or less, weak cambic B horizons and granular soil structures. These soils exhibit the highest illite/expandables and hornblende/zircon + tourmaline ratios and base saturations less than 10% throughout the entire soil profile.

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PRECAMBRIAN GEOLOGY OF THE BOULDER RIVER AREA, BEARTOOTH MOUNTAINS, MONTANA

by

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A continuing investigation of the Precambrian rocks along the Boulder River five miles south of the Stillwater Complex reveals a large two-mica granite pluton that intrudes regionally metamorphosed biotite schists, metavolcanics, and an earlier tonalite pluton. The schists display a north trending foliation parallel to compositional layering and evidence of a later deformation characterized by folding of the schistosity. The schists have a staurolite-cordierite assemblage indicative of lower amphibolite facies metamorphism of the low-pressure intermediate (Buchan) type. Very similar schists have been mapped along the Stillwater River to the east. On approaching the Stillwater Complex the schists become hornfels, pyroxene develops, and staurolite disappears. Earlier workers determined a 2.7 b.y. B.P. Rb-Sr whole rock isochron age for these schists and hornsfels.

The medium grain granite is exposed for five miles in the study areas and continues for an unknown distance to the west and south. The granite and metasedimentary rocks have undergone a later low grade metamorphism which produced a chlorite and epidote assemblage. The lack of thermal effects at the schist-granite contact suggest the granite was intruded while the country rock was still hot.

The granite strongly resembles 2.7 b.y. plutons recognized by earlier workers north of Yellowstone Park, in the Cooke City area, and south of the Stillwater Complex near Nye. If so, it lends support to the idea of a 2.7 b.y. magmatic event in the Beartooth Plateau; an event that has been recognized in the Wyoming Precambrian basement.

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