A study of selected igneous bodies of the Norris-Red Bluff area, Madison County, Montana
by John Arthur Kavanagh Yllarramendi

A thesis submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE IN APPLIED SCIENCE With a Major In Geology
Montana State University

Abstract:
The igneous bodies studied crop out in the Norris Hills, between the upper and lower Madison Valley, southeast of the Tobacco Root Mountains and northwest of the Spanish Peaks, They appear to be intrusive plugs, with surface features obscured by Quaternary deposits. In average samples the silica 'content varies between 66 per cent and 78 per cent. Chemical and normative analyses indicate that the rocks with lower and intermediate silica content are dacites. Petrographic analysis indicates the richer silica rocks are rhyolites. One andesite body is also present. The sodium content of the dacites is unusually high.

The dacites at the northern end of the upper Madison Valley are aligned, generally northwest-southeast, and lie in a zone of intensive faulting. The igneous bodies east of Norris are flow-banded dacites and breccia pipes. Pyrite-gold mineralization is present in hydrothermal quartz veins peripheral to the dacites. This mineralization seems to have been controlled by the faulting in the area.

The dacites are microcrystalline with a few phenocrysts of plagioclcise (andesine) and quartz. Microlites of feldspar and anhedral quartz grains mixed with volcanic glass form most of the groundmass. The microlites are oriented in the direction of flow. The phenocrysts in the rhyolites are orthoclase, sanidine, plagioclase,.quartz, and biotite. The groundmass is also microcrystalline, with volcanic glass appearing either as paptially crystallized microlites or as inclusions in the phenocrysts. Sericitization is abundant.

Although the Tobacco Root batholith seems to have been emplaced during early Tertiary time the igneous bodies studied appear to "be younger, probably of Eocene age. It is improbable that they were comagmatic with the batholith.

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OF THE NORRIS-RED BLUFF AREA,
MADISON COUNTY, MONTANA

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JOHN A. KAVANAGH YLLARRAMENDI

A thesis submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree

of

MASTER OF SCIENCE IN APPLIED SCIENCE

With a Major In Geology

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ABSTRACT

The igneous bodies studied crop out in the Norris Hills, between the upper and lower Madison Valley, southeast of the Tobacco Root Mountains and northwest of the Spanish Peaks. They appear to be intrusive plugs, with surface features obscured by Quaternary deposits. In average samples the silica content varies between 66 per cent and 78 per cent. Chemical and normative analyses indicate that the rocks with lower and intermediate silica content are dacites. Petrographic analysis indicates the richer silica rocks are rhyolites. One andesite body is also present. The sodium content of the dacites is unusually high.

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A STUDY OF SELECTED IGNEOUS BODIES
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INTRODUCTION

Purpose of the paper

The main purpose of this paper is to present results of a comprehensive field and laboratory study of selected igneous bodies situated between the upper and lower Madison Valley, southeast of the Tobacco Root Mountains and northwest of the Spanish Peaks. Included are their description and classific-cation, the field relations between them and neighboring igneous bodies, plus special petrological considerations.

Previous work

A general reconnaissance of the Tobacco Root Mountains has been made by W. Tansley, P.A. Schafer and L.H. Hart (1933). Some of the igneous bodies treated here were described in the report, but no petrological nor detailed field work was in-volved. Rolland R. Reid (1957) wrote about the bedrock geology of the north end of the Tobacco Root Mountains. Although the igneous bodies studied in this paper were not treated in Reid's report, this work is valuable in the attempt to determine petrological and structural relationships between the Tobacco Root batholith and the igneous bodies that surround it. G.W. Berry (1943) studied the stratigraphy and structure in the vicinity of Three Forks, Montana; geomorphic studies of the area of the Madison Valley and Norris Hills have been done by Swanson (1950), and Montagne (1960).

GEOLOGICAL SETTING

The igneous bodies studied occur over an area of about 280 square miles. They are exposed southwest, east, and northeast of the town of Norris (Fig. 1). The basement rocks are pre-Belt gneisses and schists of the Cherry Creek and Pony series. The igneous bodies cut these basement rocks and are either covered by Quaternary glacial sediments or are in close relation to them. East of the general area, Cambrian and Devonian sedimentary rocks are exposed in a southeast-northwest trend (Fig. 2), intruded at places by Tertiary coarse-grained igneous bodies, mainly quartz monzonites, diorites and other related rocks. Undifferentiated Tertiary sediments cover large areas south and north of the Tobacco Root batholith which lies close to the center of the area. The Tobacco Root batholith crops out in an elliptical shape with its longest axis having a length of about 18 miles, and its shortest axis having a length of 6 miles on the average. Glacial Quaternary sediments are predominant toward the northern end of the Madison Valley, and several distinct Quaternary surfaces can be distinguished, ranging in age from pre-Wisconsin to Late Wisconsin. The present floodplain of the Madison River forms the most recent surface.

The igneous bodies studied have been identified with letters of the alphabet (Fig. 1). South of Norris, five igneous bodies are labelled as A, B, C, D, and E. East of Norris and south of Red Bluff, two more igneous bodies, F and G, are exposed, and igneous body H is located northeast of Red Bluff.

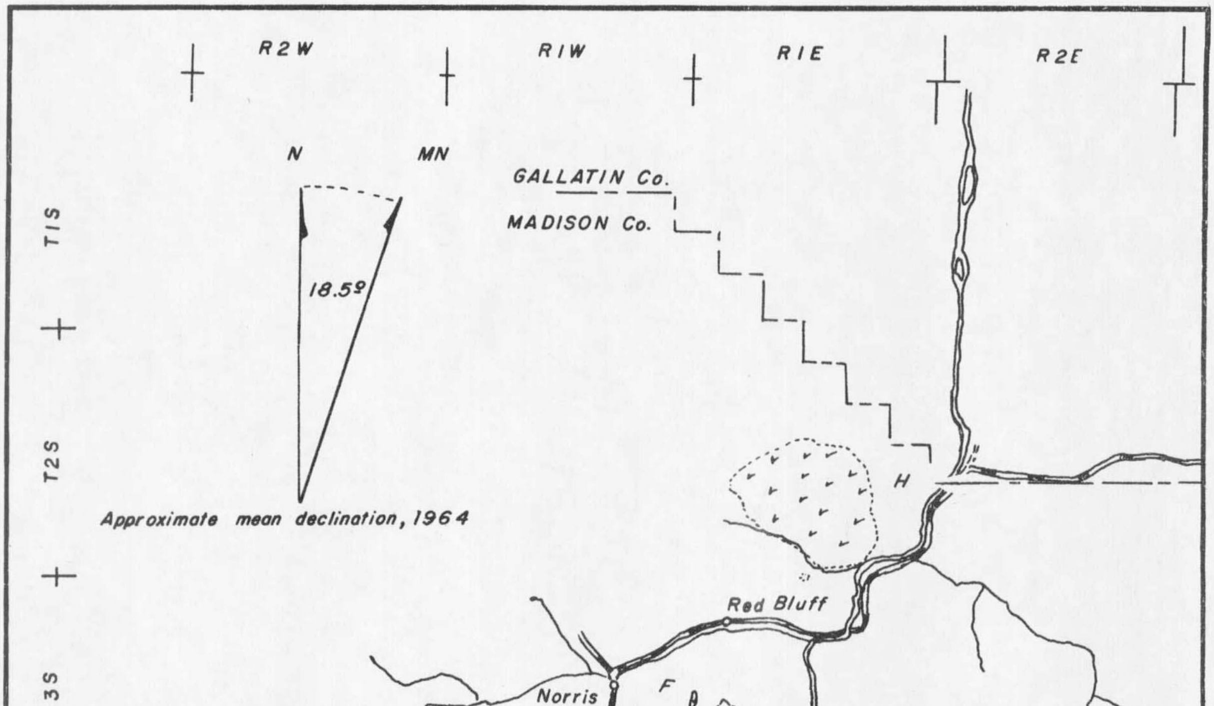
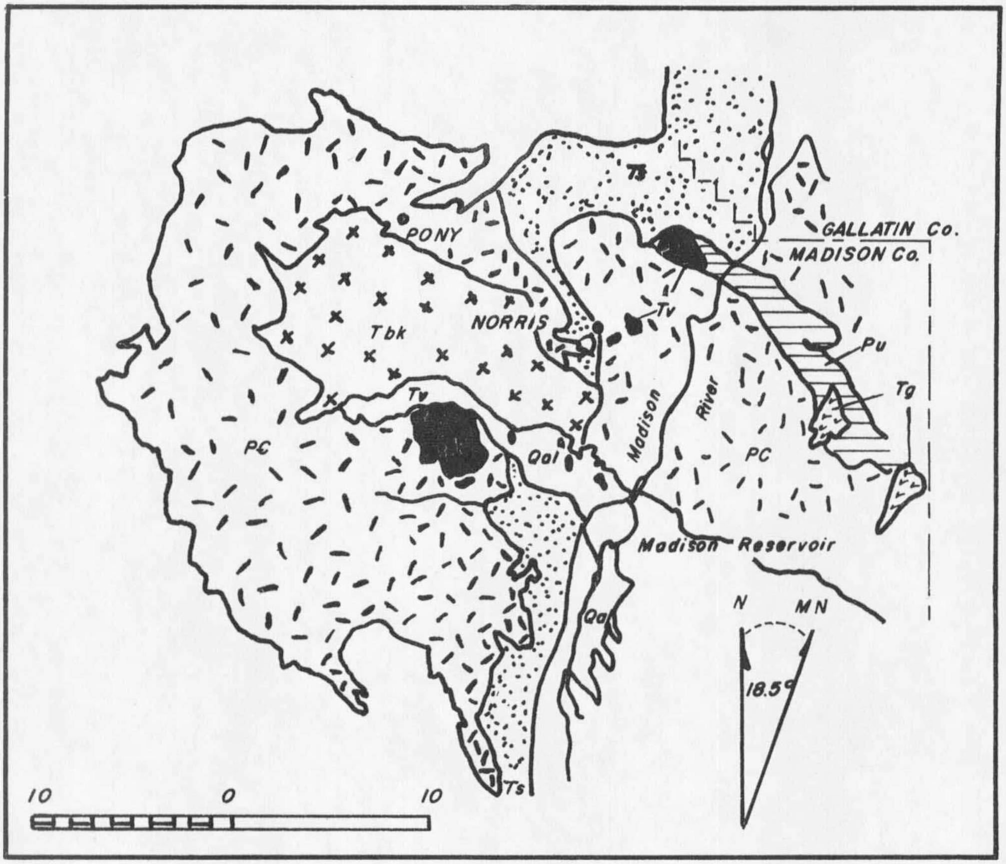


FIGURE 1. Index map of igneous bodies



Qal	Quaternary alluvium, glacial and fluvial sediments
Ts	Tertiary sediments, undifferentiated.
Tv	Tertiary volcanics, andesites, dacites and rhyolites
Tbk	Tertiary, Tobacco Root Batholith
Tg	Tertiary, intrusive coarse-grained rocks diorites, quartz monzonites and similar rocks
Pu	Paleozoic, undifferentiated
P€	Precambrian, gneisses and schists

Modified from Geologic Map of Montana (1955), compiled by
C. P. Ross,
D. A. Andrews, and
I. J. Witkind.

FIGURE 2. General geology of the area

GENERAL GEOLOGY OF IGNEOUS BODIES

Igneous bodies A and B

Igneous bodies A and B are acid igneous rock; megascopic, plus chemical and petrographic analysis (see Petrography) permit classification of these rocks as dacites. These intrusive dacites are exposed in the general region of Meadow Creek. Quaternary sediments and alluvium obscure border relationships with the host rock. The boundaries of the igneous bodies were determined by float, because contacts do not crop out. Cooling cracks are found throughout the dacites of this body, forming plates which range in thickness between 3 and 8 mm., according to the amount of exfoliation. The cooling cracks give the dacites a peculiar form in outcrops (Plate 1, Fig. 2), and there is microscopic evidence that these cracks are oriented parallel to the direction of flow. The tendency of the igneous bodies to form parallel plates aligned with the direction of flow will be referred to from now on as fissility. The structure of the bodies was determined by measuring attitudes of the flow, as indicated by this fissility. The general structure of igneous body A shows

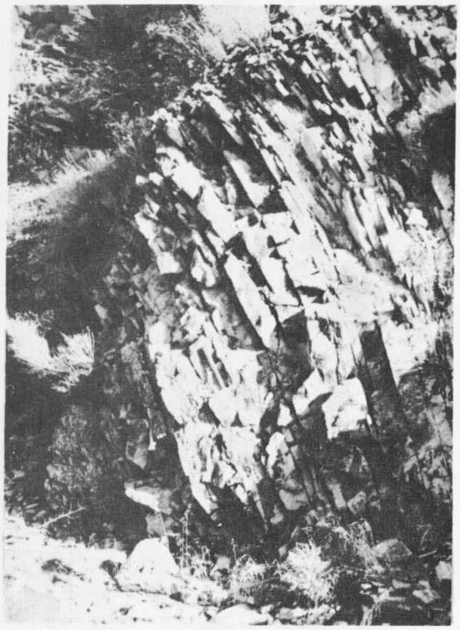


PLATE ONE

FIGURE 1. Igneous body C. Dacite intrusion.
Fissility conforms with the direction of flow.

FIGURE 2. Igneous body C. Dacite extrusion.
Arrow shows direction of flow.

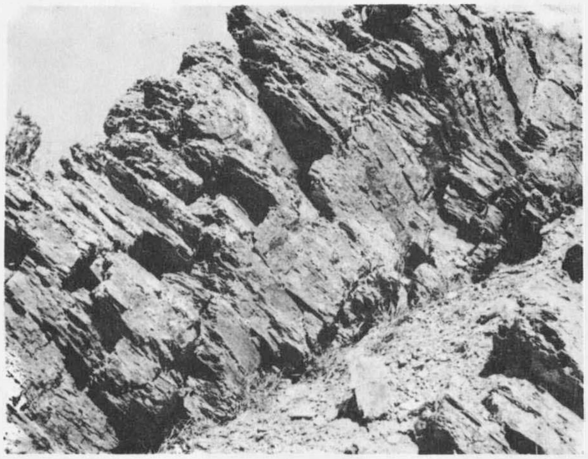
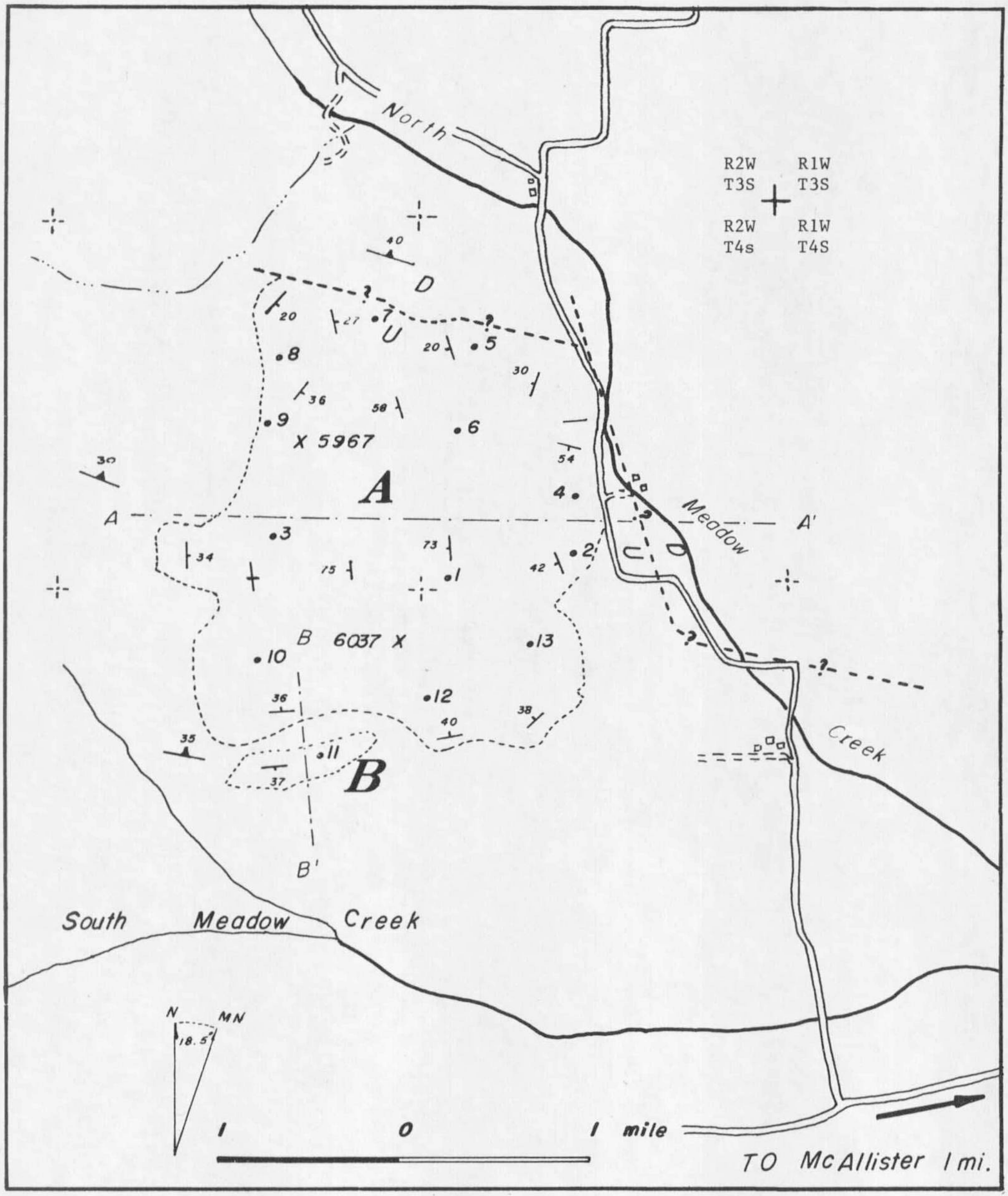


FIGURE 3.

Igneous body A.
Fissility in dacites. This fissility conforms with the last direction of flow.

two patterns; one at the southern end and another at the northern end of the area. At the southern end (Fig. 3) -if outcrop B is excluded- a distinguishable vent or plug structure appears, with the fissility of the dacites dipping concentrically inward and the dip also steepening inward, towards the southwest portion of the igneous body. The fissility of igneous body B does not conform with this pattern, dipping uniformly southward. This pattern suggests that the dacites of body B represent a separate intrusion and are not part of the main body. In the northern part of the main igneous body, fissility dips inward from the east and west but no inward dip is found along the northern boundary. At a lower topographic elevation and at the eastern boundary of the igneous body, a small exposure of highly fractured dacite is found. The fissility of this outcrop is obscured by another set of cracks at right angles to the cooling cracks. The overlying fissile dacite dips toward the south. Field evidence suggests two different intrusions: a small intrusion which produced the dacites of outcrop B and the underlying dacites of the northeastern part of the main body, and a later, more voluminous intrusion of later dacite, which partially covered the earlier intruded rocks.



Attitude of flow structure (dip showing where measurable)

Inferred fault

Attitude of gneiss foliation

Approximate boundary of igneous bodies

Sampling station

FIGURE 3. Geologic map of igneous bodies A and B

The attitude of the later dacite on the northeastern part of the igneous body could be attributed to surface rather than vent flow. Subsequent erosion has eliminated most of the surface flow farther away from the source. Faulting has probably occurred at two places: on the eastern side of the igneous body, where the so-called North Meadow Creek fault has been mapped (Shelden, 1960; p. 178-184) trending north-south on the eastern side of the igneous body and for which scant evidence exists, and another northwest-southeast fault evidenced by the sudden drop in slope of the igneous body, the disappearance of dacite and the interruption of the igneous body's structure. These faults are normal (?) with the upthrown block in the dacites, and accentuate the graben-like structure of Madison Valley (Montagne, personal communication). Two cross sections (Fig. 4) illustrate the structure. East-west cross section A - A' shows the vent structure and cross section B - B' shows the relationship between the dacite of the main body and the dacite of igneous body B.

Igneous body C

Igneous body C is about one half-mile due east from igneous body A. It is noticeably smaller than A and B, and lies at a

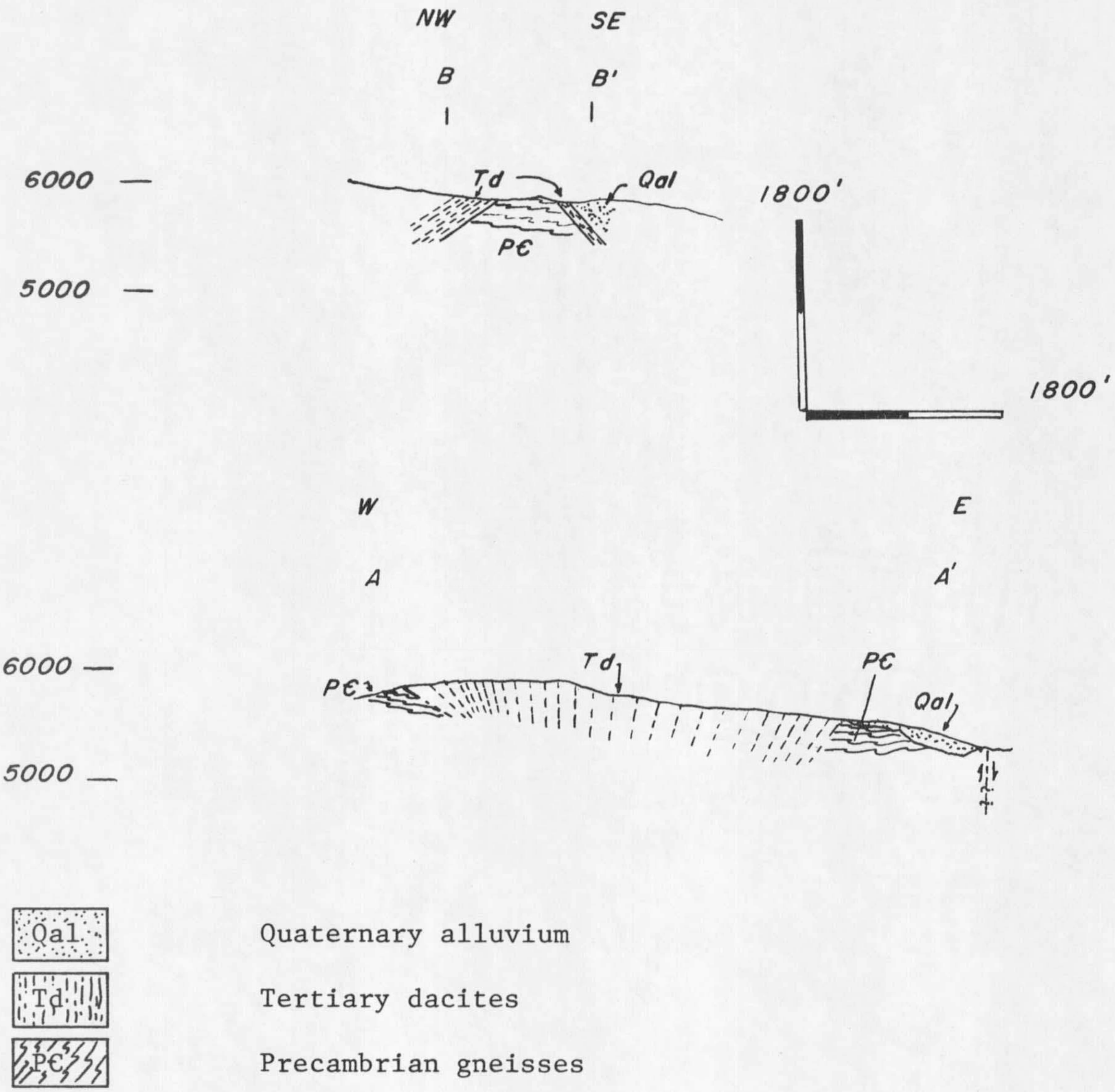


FIGURE 4. Cross section of igneous bodies A and B
Location of cross sections shown on FIGURE 3.

lower topographic elevation. Two distinct rock types are shown: an underlying andesite restricted in horizontal outcrop width to about forty feet, and an overlying dacite, which in places was intruded through the andesite and lies conformably on it in the rest of the outcrop. The andesites show the long axes of minerals plunging 16 degrees to the southeast. Fissility of the overlying dacite dips steeply in the southern part and 30 - 40 degrees northeastward in the rest of the body. The dacite is truncated by a pre-Wisconsin geomorphic surface.

The local structure (Fig. 5) suggests either an early andesitic extrusion, if the dip of the structure has not been disturbed, or an early andesite intrusion which has been tilted by later faulting. This andesite was later cut by the dacites on their way to the surface (Fig. 5, cross section C - C'). Once the dacites reached the surface, they extended horizontally over the paleosurface (Plate 1, Fig. 1, 2). Subsequent faulting could have tilted these dacites eastward. Glacial erosion and deposition on the pre-Wisconsin surface complete the picture.

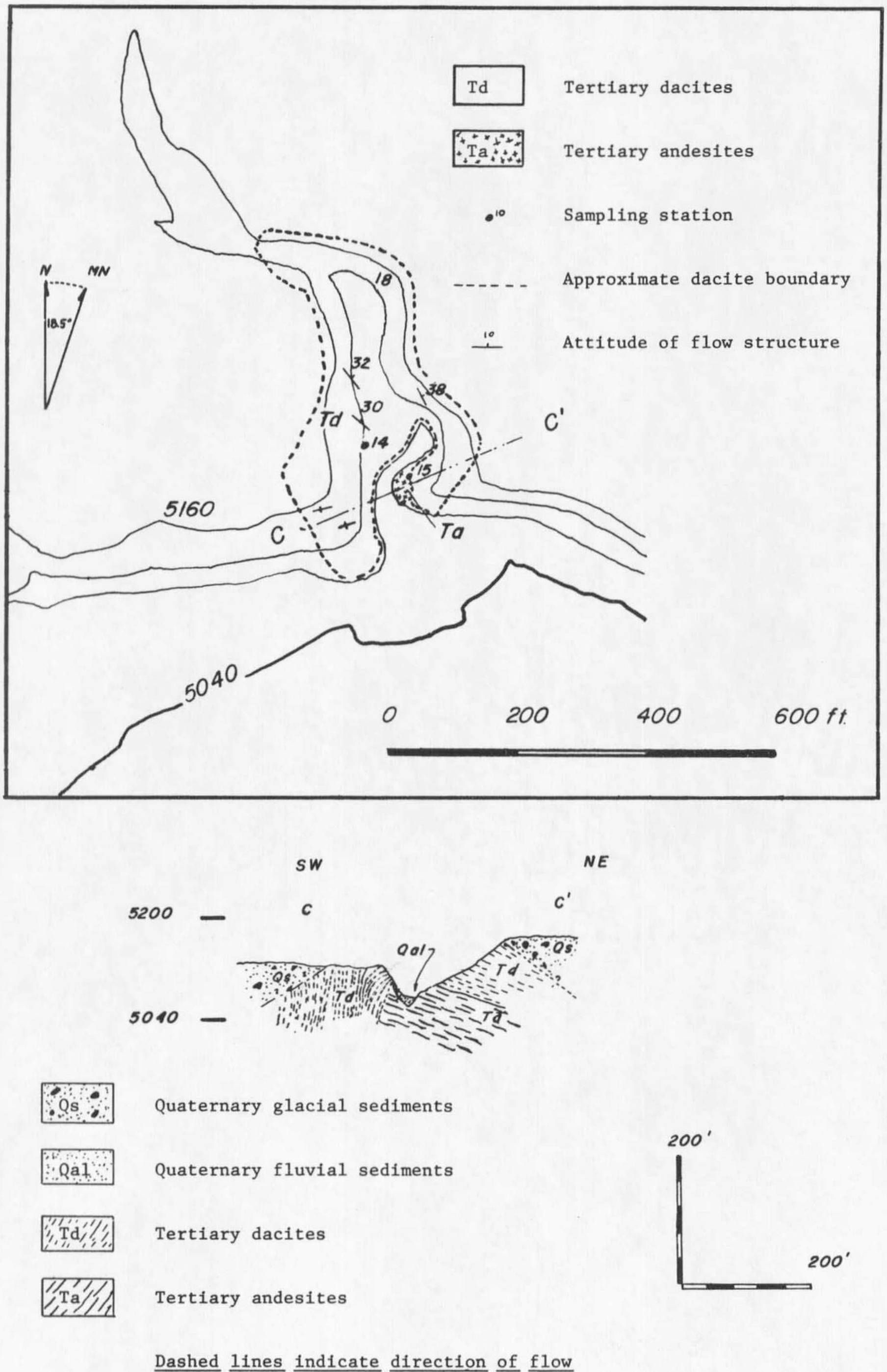
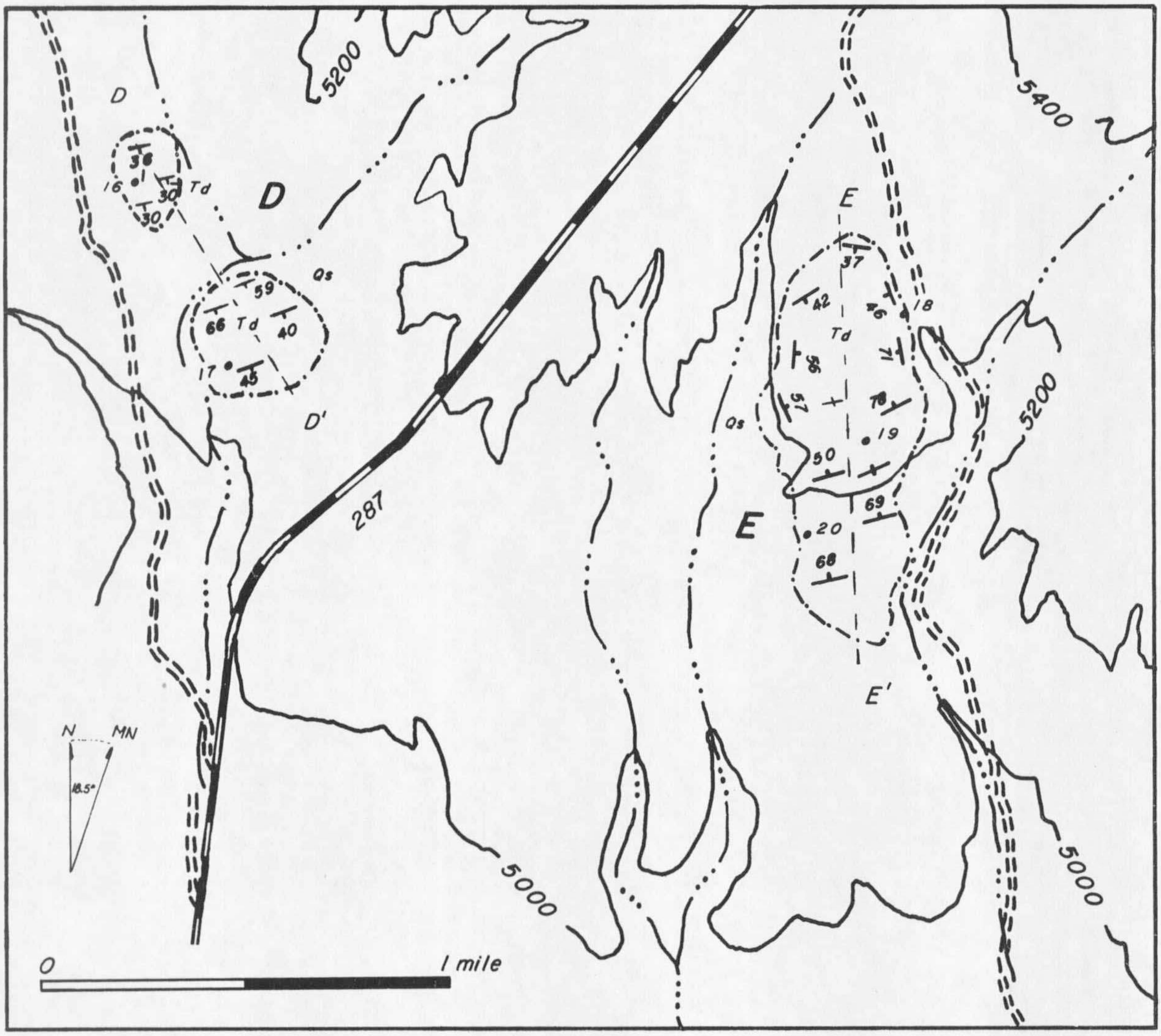


FIGURE 5. Geologic map and cross section of igneous body C

T4S, R1W, Section 20

Igneous bodies D and E

North of the town of McAllister, igneous bodies D and E crop out. These outcrops are the most uniform from the petrological point of view (See Petrography). They exhibit fissility and are located at a lower elevation than the pre-Wisconsin surface which cuts the top of igneous body C. The sedimentary cover obscures the field relationships between the igneous bodies and the pre-Wisconsin glacial sediments. Nearby bedrock exposures are Precambrian gneisses. Igneous body D (Fig. 6) comprises two outcrops separated in space by fluvial sediments deposited between them by a local intermittent stream (Fig. 7, cross section D - D'). The strike of fissility of both outcrops is quite parallel, but the fissility dip of the northernmost exposure is not as steep as that of the southernmost one. Hand excavation was done by the writer in the alluvium between the two exposures, but no fresh rock was encountered. This indicates that either there is no connection between the two exposures or that fluvial sediments are deeper than the depth of excavation (about 4 ft.). The continuous pattern of the igneous body (Fig. 7, D - D') suggests the latter explanation. It is possible that both exposures belong to the



Qs Quaternary glacial sediments

Td Tertiary dacites

Attitude of flow structure

Approximate dacite boundary

Sampling station

FIGURE 6. Geologic map of igneous bodies D and E T4S, R1W, Sections 21, 22, and 27

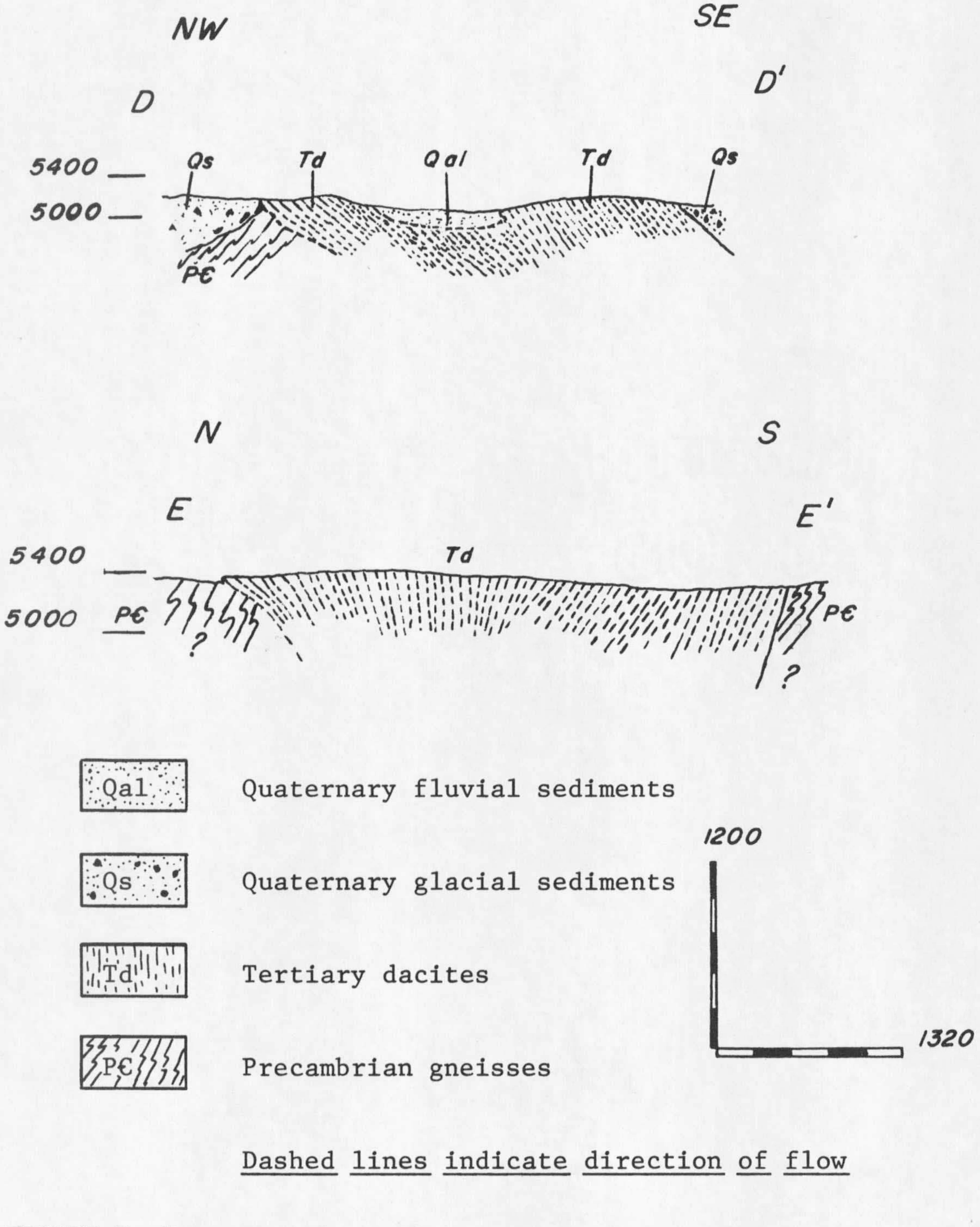


FIGURE 7. Cross sections of igneous bodies D and E
Location of Cross sections shown in FIGURE 6

same plug. Glacial sediments surround this exposure, but the fact that the gneisses are exposed near the igneous body suggests that these dacites (see Petrography) were intruded into Precambrian basement rocks.

Igneous body E is located east of body D (Fig. 6), and it approximates in outline an ellipse with its long axis oriented almost north-south. The highest elevation of this body is 5391 ft., with the Quaternary sediments beginning at approximately 5200 ft. Fissility was also used here as a criterion for determination of flow direction. Although the northernmost end of the body shows vent characteristics, with the fissility of the dacites dipping concentrically toward the center of the igneous body, the southern end seems more indicative of a dike-like structure, with the closely spaced cracks dipping uniformly and steeply toward the north. It is assumed that the dacites cut through the Precambrian gneisses (Fig. 7, cross section E - E').

Igneous body F

South of Red Bluff and east of Norris (Fig. 1), there are two igneous bodies which show similarities in structure and petrology. Flow-banded dacites, breccias, and glassy flow-banded dacites are three distinctive lithologic units of these two outcrops (see Petrography). The westernmost igneous body has been labelled F. Prospect holes are found throughout the area in which the dacite is mapped. The prospect holes generally follow quartz veins, or try to intercept them at depth. Some of the quartz veins may be a product of metamorphism, and some may be hydrothermal veins, having pyrite-gold mineralization. The differentiation between the two kinds is rather difficult. Only the hydrothermal quartz veins are mineralized, whereas the quartz veins of metamorphic origin are barren of metallic minerals. Three lithological units are found in igneous body F (Fig. 8):

a. Flow banded dacite, light in color and showing a moderate degree of fissility, not as pronounced as that in the igneous bodies south of Norris.

b. Breccia, containing fragments of dacite, some of them flow banded, embedded in a glassy, microcrystalline matrix.

c. Faintly banded dacite, with characteristic perlitic cracks, darker-colored than the other units, and located near the contact with the Precambrian gneisses on the southern end of the igneous body.

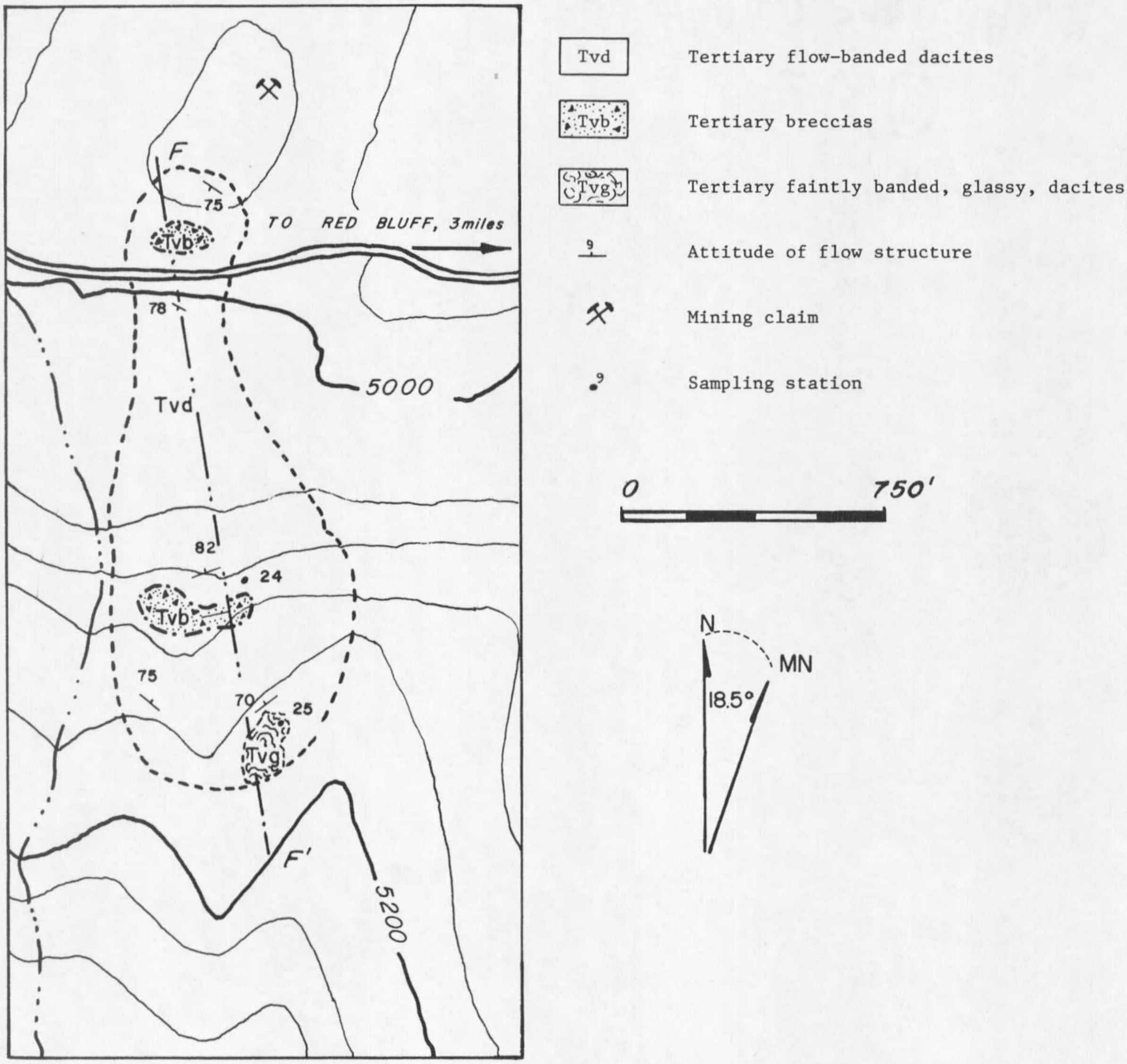
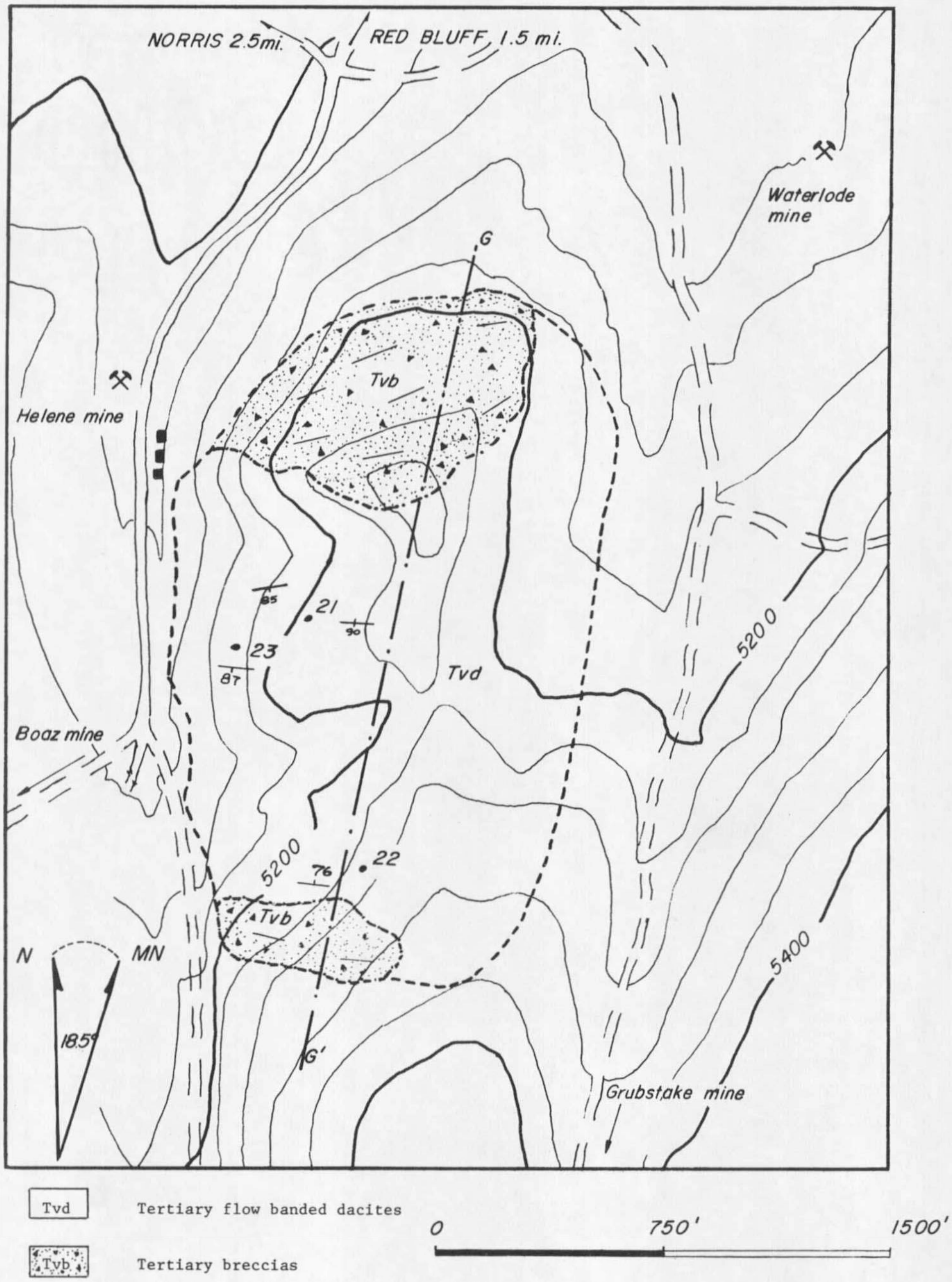


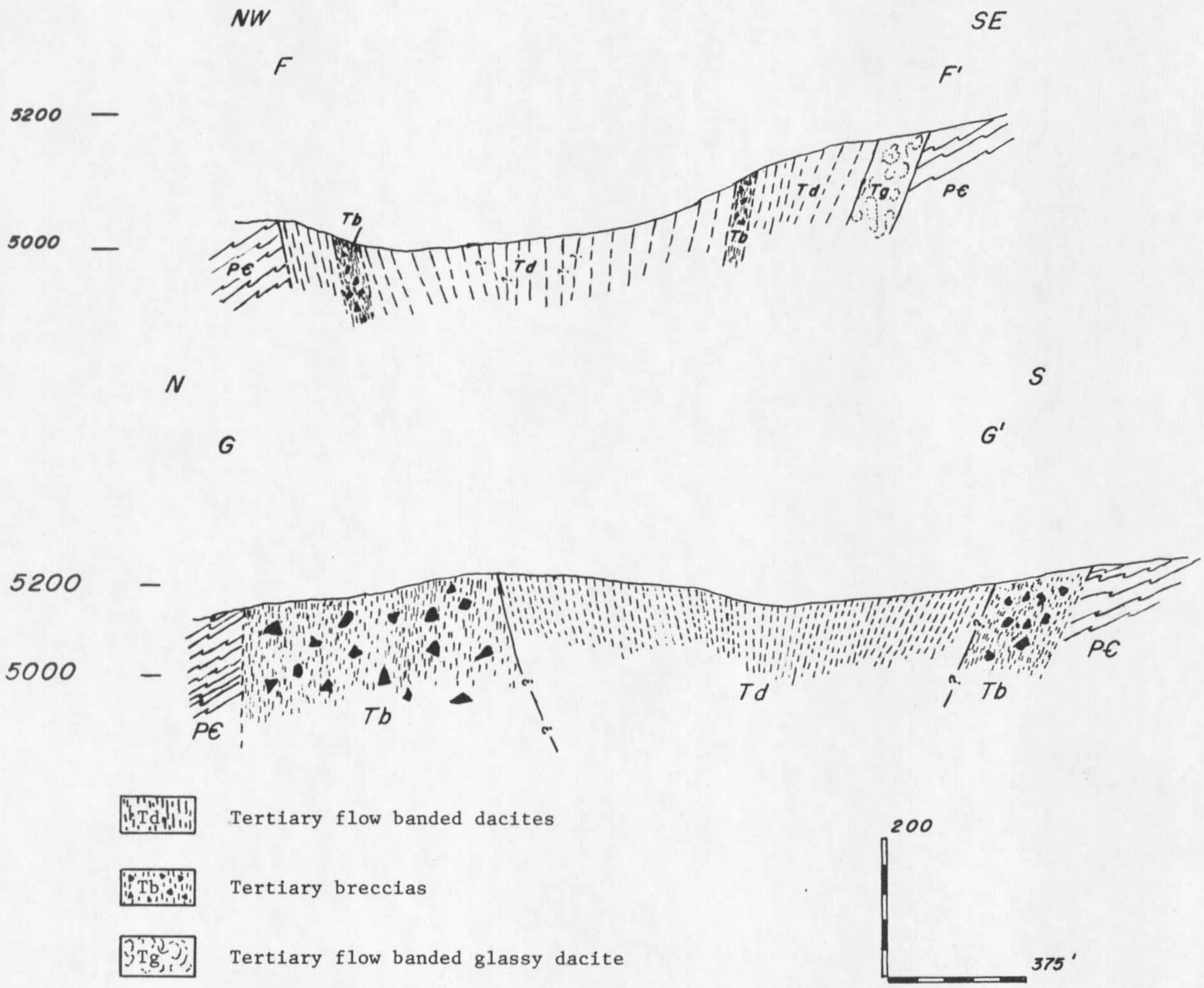
FIGURE 8. Geologic map of igneous body F T3S, R1E, Section 19, NE quarter.

Fissility dips steeply toward the center. The flow banding of the dacites is parallel to the plane of fissility (Fig. 10, cross section F - F'). Breccias are found within the igneous body proper, which helps explain the fact that only dacitic fragments are found. The attitude of breccias is rather obscure but the lack of local intensive disturbance in the dacites suggests that the breccias were emplaced along the same planes as the dacites (Fig. 10, cross section F - F'). However the possibility of vertical breccia pipes in which surface boundary features have been eroded, cannot be discarded. The dacite fragments comprising most of the breccia could have been obtained from a deeper zone, thereby suggesting autobrecciation. The glassy, faintly flow-banded dacites at the southern end of the igneous body also are found on the west side although not as distinctive outcrops but rather as float and with a varying degree of glassiness. They could have been emplaced either as a homogeneous viscous crystal mush which cooled rather rapidly, or as very viscous liquid that did not cool so rapidly; the perlite cracks could be due to contraction of the homogeneous material upon cooling (Harker, 1962, p. 137-172).



Tvd	Tertiary flow banded dacites
Tvb	Tertiary breccias
	Attitude of flow structure (dip showing where measurable)
	Mining claims
	Sampling stations

FIGURE 9. Geologic map of igneous body G T3S, R1E, Section 19



Td — Tertiary flow banded dacites

Tb — Tertiary breccias

Tg — Tertiary flow banded glassy dacite

PЄ — Precambrian gneisses

Dashed lines indicate direction of flow

FIGURE 10. Cross sections of igneous bodies F and G
Location of cross sections shown on FIGURE 8 and FIGURE 9

Igneous body G

Two lithologic units comprise igneous body G (Fig. 9). The more voluminous unit, although not having the most distinctive outcrops, is a flow banded dacite, very similar to the one found in igneous body F. This dacite also has fissility aligned parallel to the flow banding. Most of the exposures were found at or near exploration holes dug by prospectors. The second lithologic unit is breccia, carrying angular to subangular dacite fragments embedded in a glassy matrix. The breccia outcrops are quite prominent and on the northern end of the igneous body the fissility appears to dip almost vertically. The flow banded dacites in the middle of the outcrop show steep dip toward the south, whereas in the southernmost exposures fissility dips toward the north. The east and west contacts could not be determined except by float, and thus structure is somewhat uncertain. A north northeast-south southwest cross section (Fig. 10, cross section G - G') suggests a vent. The uncertainty of attitudes on the western and southern boundaries of the igneous body limits an understanding of the structure; the structure illustrated is assumed. The breccias seem to be a product of late viscous liquids that were pushed outward by pressure away from the magmatic chamber. These liquids probably moved along the same weakness planes through which the dacites originally traveled, breaking and scraping the partially solidified dacites. Although the breccias are located near or at the contact between the igneous body and the surrounding Precambrian gneisses, they are monolithologic, with only dacite fragments. No gneissic material was seen in them. The fluid probably had too much viscosity to penetrate and rip off pieces of the metamorphic rocks. Steep contacts suggest intrusive breccias.

Igneous body H

Igneous body H is located near where the Madison River leaves the Madison Canyon (Figs. 1, 11) and it is known locally as Red Mountain. The lithological units present in this igneous body are:

a. Flow-banded rhyolite (see Petrography), light pink to reddish in color, showing alternate bands of light and red color, due to hematitic alteration.

b. Monolithologic breccia, containing fragments of rhyolite, with or without flow-banding, texturally very similar to the breccias described before.

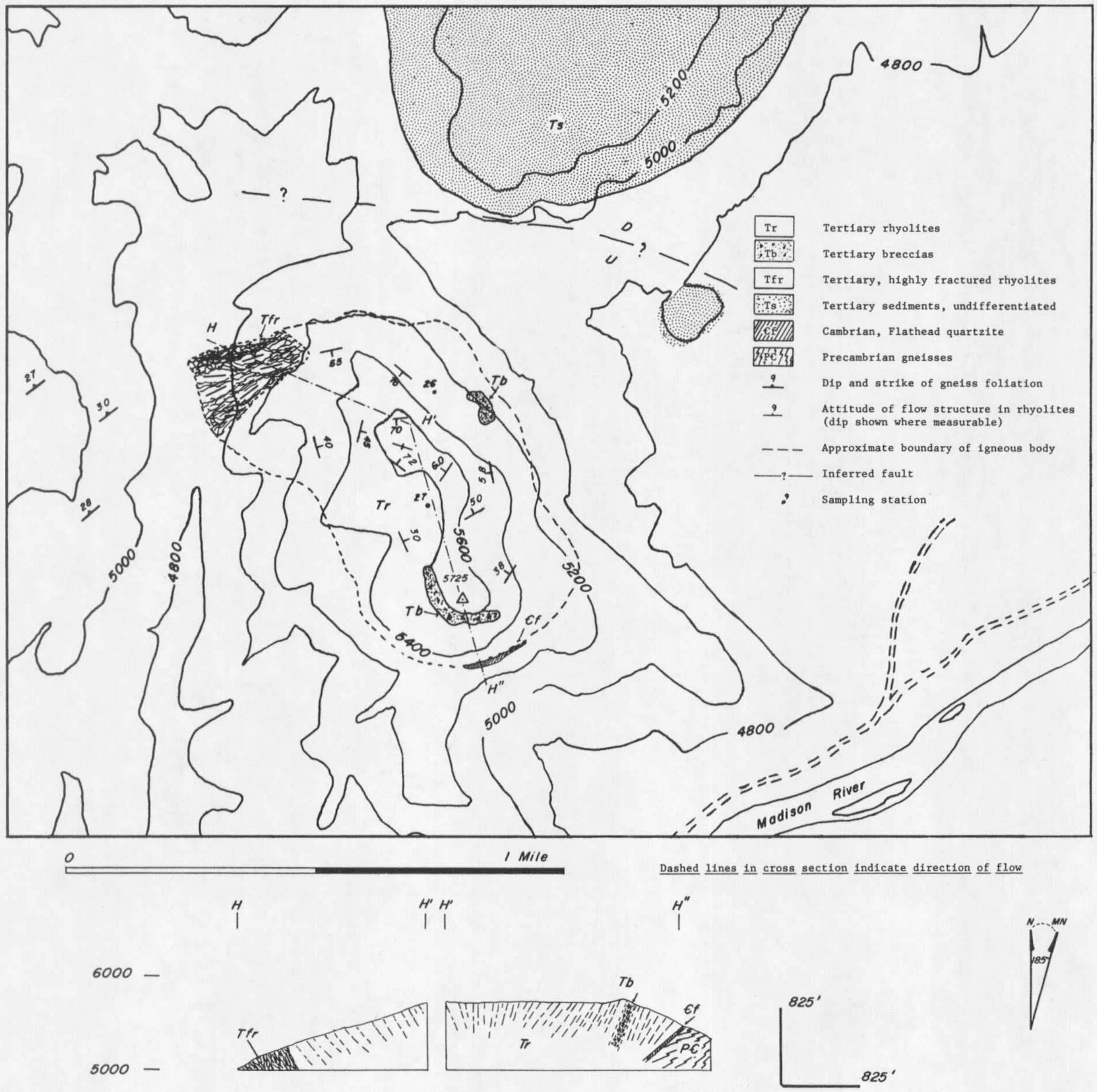


FIGURE 11. Geologic map and cross section of igneous body H

c. In-place breccia (Plate 2, Fig. 2) characterized by a number of small shear fractures. The breccia does not have large areal extent, but is rather localized in the northwestern end of the igneous body. The composition of the breccia is rhyolitic, and the original rocks have not been displaced far in space but have been broken and fractured throughout.

Fissility and flow banding are parallel in this igneous body, as they are in the other bodies showing both characteristics. A vent is suggested by the attitude of flow structure. A large fault lies near the eastern and northern part of the igneous body, and is quite evident owing to displacement of neighboring Tertiary strata. Faulting may have uplifted the block containing the rhyolite, and subsequent erosion probably has obliterated sediments that may have existed on the uplifted side.

FIGURE 1. Breccia-dacite contact zone, igneous body G.
T.3.S.,R.1.E.,S 19.

PLATE TWO

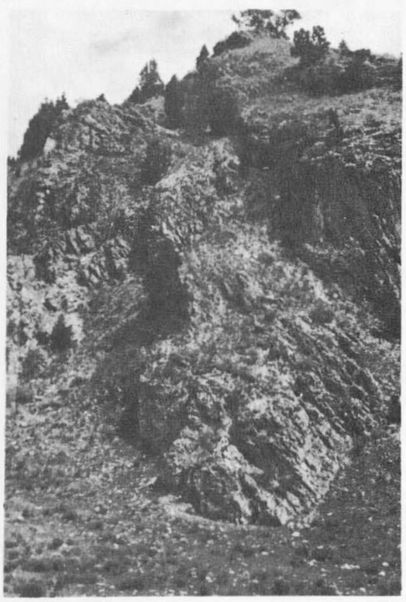


FIGURE 2. Highly fractured rhyolite, igneous body H
T.2.S.,R.1.E.,S 34.

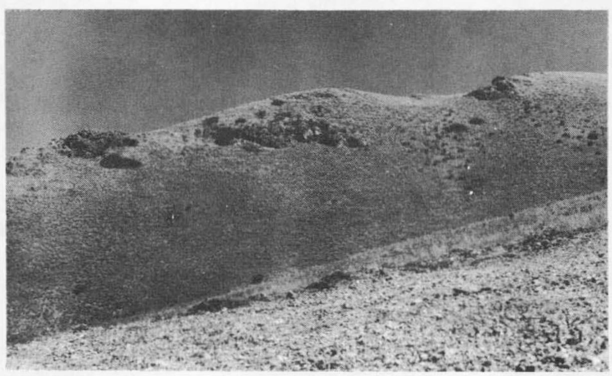


FIGURE 3. Same location as FIGURE 1, igneous body G.
Flow-banded dacite float in foreground,
breccia outcrop in background.

CHEMICAL ANALYSIS OF SAMPLES

Sampling

Each igneous body was sampled thoroughly, and several specimens were taken from each available outcrop. Selected samples were then analyzed for silica content, either by the writer or by Technical Services Laboratories, of Ontario, Canada. Comparison of the author's results with those obtained from the Laboratories shows that, on the average, silica content in the author's analyses was higher by 3 to 5 per cent, probably due to the fact that the author was measuring all insoluble material rather than only silica. Consequently, all the results obtained by the author have been corrected downward by an average of 4 per cent.

All sampling stations have been pinpointed by number on the maps of their respective igneous bodies.