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Sheriff, S.D. Gunderson, J.A.

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AGE OF THE ADEL MOUNTAIN VOLCANIC FIELD, WEST-CENTRAL MONTANA

STEVEN D. SHERIFF — *Department of Geology, University of Montana, Missoula, MT 59812*
JAY A. GUNDERSON — *B.P. Exploration, 9401 SW Freeway, S331, Houston, TX 77074*

GEOLOGY

The Adel Mountain volcanic field in western Montana (lat 47.20°N, long 111.85°W) covers approximately 900 km², (fig. 1). The volcanic rocks unconformably overlie a folded and thrusted Cretaceous sedimentary section and occupy a structural depression which parallels the eastern edge of Montana's disturbed belt. The southwestern edge of Adel Mountain volcanic field is deformed by Late Cretaceous to Paleocene folds and imbricate thrusts.

The Adel Mountains were first mapped by Lyons (1944) as a 1,000 m thick Late Cretaceous volcanic sequence comprised primarily of large volumes of shonkinite (trachybasalt), a potassium-rich basalt of approximately equal proportions of K-feldspar and pyroxene. Schmidt (1972a, 1972b, 1977, 1978), Mudge and others (1982), and Soward (1975a, 1975b) provide modern high quality geologic maps of the Adel Mountain volcanic field and surrounding area. Swenson (1988) completed a detailed geologic map of the southern portion of the Adel Mountain volcanic field, verifying and extending the stratigraphic and structural relations of Lyons (1944).

The Adel Mountain volcanic rocks include flows, flow breccias, volcanic conglomerates, and associated intrusives, all of similar composition. The extrusive rocks are dominated by flow breccias and volcanic conglomerates, particularly in the southwestern portion of the field. As in many volcanic fields, flows and breccias are poorly bedded, but structural attitudes can usually be measured by examining outcrops both mesoscopically and megascopically. The entire extrusive package has been mildly deformed and mineralogically altered by zeolitic replacements and oxidation (Lyons, 1944; Beall, 1973).

The intrusive rocks, further described by Beall (1972, 1973) and Whiting (1977), include dikes, sills, plugs, other irregular bodies, and two concentric arcs of laccoliths which lie 18 and 23 km north of the volcanic center (fig. 1). The most striking feature of the entire volcanic assemblage is the enormous number of dikes which emanate radially from its center, almost all crosscut the extrusives. These dikes range from 10's of centimeters to 10's of meters in width. The larger dikes make obvious topographic features on 1:62,500 maps for up to 30 km, they often feed tangentially attached laccoliths (Hyndman and Alt, 1987) which feather into the host sedimentary rocks. These late dikes are undeformed and are almost always vertical.

PREVIOUS WORK ON THE AGE OF THE ADEL MOUNTAIN VOLCANIC ROCKS

The age of the Adel Mountain volcanic rocks has never been reliably established or agreed on by geologists working with the rocks. Various authors have considered the Adel Volcanic rocks to be Late Cretaceous and/or early Tertiary. The Adel Volcanic rocks were first dated as Late Cretaceous based on two plant fossils found in the volcanic conglomerates (Lyons, 1944). Support for a Cretaceous age was added in a March 1984 USGS Geologic Division Newsletter which credited Mehnert and Cebula with obtaining K-Ar dates (unpublished) of about 75 ± 2.3 Ma and 72.9 ± 2.1 Ma on hornblendes and biotites from samples of trachybasalt. The samples for these K-Ar dates were taken in 1969–1970 from Lyons' (1944) lower breccia unit near Wolf Creek, Montana. Lyons (1944) considered these volcanic rocks to be the basal portion of the Adel Mountain volcanic rocks. However, Lyons' (1944) lower breccia unit near Wolf Creek is now recognized as being a member of the Two Medicine Formation which is related to the Late Cretaceous Elkhorn Mountains volcanic field (Schmidt, 1972a), not the Adel Mountain volcanic field. Thus the two radiometric dates from the USGS newsletter are probably not from rocks of the Adel Mountain volcanic field. Lithologically, the Adel Mountain volcanic rocks are similar to nearby early Tertiary shonkinitic centers in the Highwood mountains (Larsen and others, 1939) and Bearpaw mountains (Hearn, 1976). Because of this similarity some (e.g., Hyndman and Alt, 1987) have considered the Adel Mountain volcanic rocks to be early Tertiary in age.

PALEOMAGNETIC CONSIDERATIONS

Our initial interest in the Adel Mountain volcanic field was fueled by a desire to fine-tune North America's apparent polar wander path for the Late Cretaceous. Previous knowledge of this portion of the polar wander path was mostly limited to results from rocks in the deformed and extended cordillera. Four estimates of the Late Cretaceous pole position for North America have been used in recent compilations. These four are: 1) the Elkhorn Mountains volcanic field (75–80 Ma) of west-central Montana (Hanna, 1967, 1973); 2) the Livingston Formation (~80 Ma) pole from southwestern Montana (Swenson and McWilliams, 1989); 3) the Maudlow Formation (75–83 Ma) pole from southwestern Montana (Swenson and McWilliams, 1989); and 4) the ~72 Ma pole from the Roskruge volcanic rocks of southern Arizona (Vugteveen and others, 1981). The 85–89 Ma Niobrara Formation of Wyoming, Colorado, and Kansas (Shive and Frerichs, 1974) also provides an estimate of the Late Cretaceous pole position from sedimentary sections on the craton. Unfortunately, rocks on the allochthonous upper plate of crustal scale deformations are not the best for establishing reliable reference pole positions, and sedimentary rocks are always suspect because they are regularly not reliable recorders of the ancient magnetic inclination. These problems with previous investigations warranted further investigation of the Late Cretaceous pole position provided that suitable, relatively undeformed Cretaceous volcanic rocks could be located.

The location of the Adel Mountain volcanic rocks, beyond the eastern edge of major fold and thrust deformation and east of Tertiary extension enhances their value for contributing information about the Late Cretaceous pole position. However, paleomagnetic results must be well dated. To use our paleomagnetic results for the polar wandering path, (Gunderson 1989; Gunderson and Sheriff, in press) from the Adel Mountain volcanic field we needed to be certain of their age.

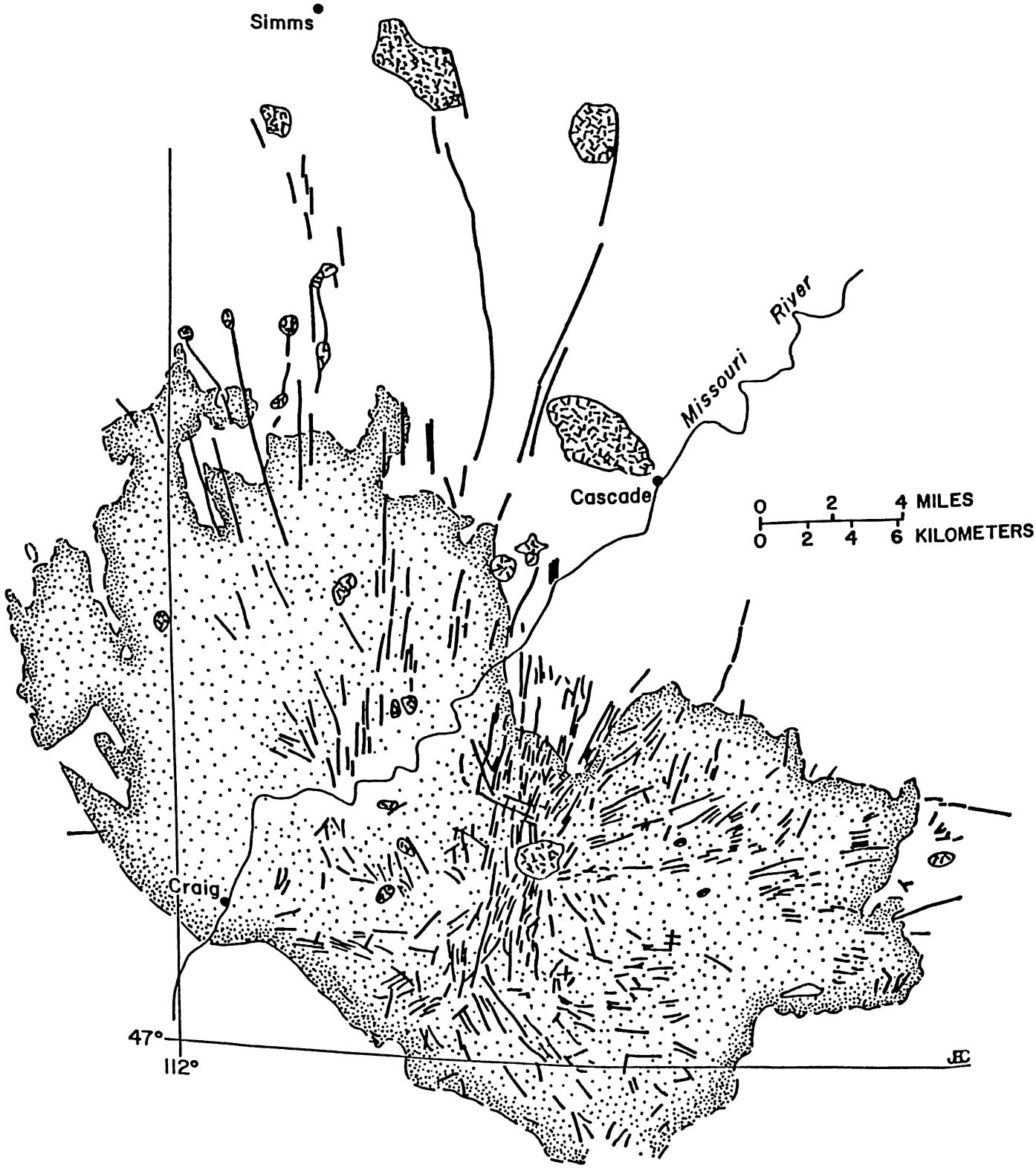

FIGURE 1. Index map and general geologic map of the northern Adel Mountains, Montana (from Hyndman and Alt, 1987). The stippled area is the volcanic rocks, heavy lines are dikes. The hachured areas are shonkinite intrusions; those north of the volcanic pile are laccoliths.

RESULTS

To add credence to the dating of the Adel Mountain volcanic rocks, we obtained two new K-Ar age dates from two different units. One, a whole-rock K-Ar date of 81.1 ± 3.5 Ma from a flow deep in the volcanic pile (site 88AV12) probably represents very early volcanism. A K-Ar determination on biotites from one of the late shonkinite dikes that crosscut the volcanic pile represents late igneous activity at 71.2 ± 2.7 Ma. These dates help constrain Adel Mountain volcanic activity to the Late Cretaceous (ca. 81–71 Ma).

The dates are consistent with field observations in that essentially all dikes crosscut the older flows. The dates are also consistent with our paleomagnetic results (Gunderson, 1989; Gunderson and Sheriff, in press). We collected paleomagnetic sites in 34 individual flows or dikes, none were magnetized in a reversed magnetic field. The Late Cretaceous was a time of limited magnetic reversals relative to the Early Tertiary (e.g., Harland and others, 1982). For example, the geomagnetic field maintained a normal polarity state for more than 80% of the time from 70 Ma to 81 Ma. Thus, the paleomagnetic data also support a Late Cretaceous age.

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SAMPLE DESCRIPTIONS

1. *88AV01* (Geochron #B-8578) K-Ar
   Shonkinite dike with phenocrysts of plagioclase, clinopyroxene, very fresh biotite and magnetite (47.29°N, 111.94°W; outcrop is obvious where the dike crosses the St. Peter Mission road in the NW¼, NW¼, S25,T18N,R3W; Cascade Co., MT). *Analytical data:* K = 5.469% (^{40}K = 6.524 ppm); ^{40}Ar = 0.02754 ppm; ^{40}Ar/(total ^{40}Ar) = 43.5%. *Collected by:* S. D. Sheriff. *Dated by:* Geochron Laboratories, Inc.
   (biotite) 71.2 ± 2.7 Ma

2. *88AV12* (Geochron #R-8585) K-Ar
   Fresh shonkinite flow with no phenocrysts (47.14°N, 111.86°W, NW¼, NE¼, S21,T16N,R2W; Cascade Co., MT). *Analytical data:* K = 1.231% (^{40}K = 1.468 ppm); ^{40}Ar = 0.007076 ppm; ^{40}Ar/(total ^{40}Ar) = 70.0%. *Collected by:* J. A. Gunderson. *Dated by:* Geochron Laboratories, Inc.
   (whole rock) 81.1 ± 3.5 Ma

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