GEOCHRONOLOGICAL EVIDENCE FOR MESO- AND NEOPROTEROZOIC MAFIC MAGMATISM ALONG THE WESTERN MARGIN OF THE WYOMING CRATON

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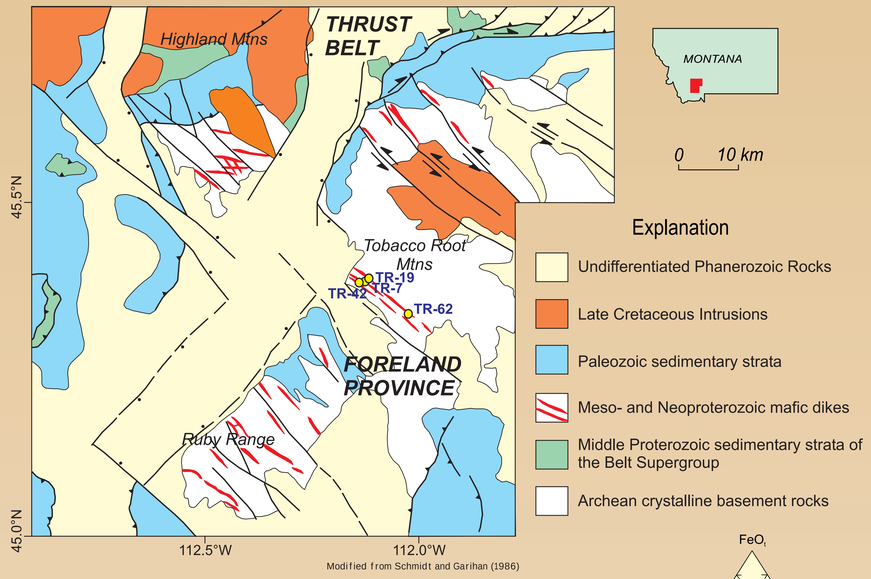
Abstract

Isotopic dating of mafic dikes in the southern Tobacco Root Mountains of southwestern Montana provides evidence for two distinct episodes of subparallel Proterozoic mafic magmatism separated by about 700 m.y. Previously published geochemical data from dikes in the southern Tobacco Root Mountains had identified three geochemical groups (termed groups A, B, and C) with apparent Rb-Sr ages of 1455 Ma (group A) and 1100-1120 Ma (group B and C). Sm-Nd dating of geochemical group A/C dikes yields a mineral isochron age of 1447 ± 49 Ma that is interpreted to represent the emplacement age of the dikes. This age is similar to published U-Pb dates from mafic sills that intrude the nearby Mesoproterozoic Belt Supergroup and dikes that cut the Laramide basement-cored uplifts of the Archean Wyoming Province. We suggest that the mafic magmatism recorded by the southern Tobacco Root Mountains group A/C dikes probably corresponds with continental extension that accompanied development of the Mesoproterozoic Belt Basin. U-Pb dating of baddeleyite from the group B dikes provides evidence for a younger magmatic event with an age of 782.4 ± 4.9 Ma (95% confidence; ± 7.1 Ma incorporating uranium decay constant errors). This date is similar to isotopic dates from Neoproterozoic mafic dikes and sills exposed elsewhere in uplifts of the Rocky Mountain foreland and that intrude the Mesoproterozoic strata of the Belt Supergroup. $^{40}Ar/^{39}Ar$ dates from hornblende in the group B dikes and biotite from a baked contact zone from one of the dikes yield similar isotopic dates indicating that they have not been disturbed by subsequent (Laramide) tectonothermal events. Geochronologic data from elsewhere in the northern Cordillera and Canadian Shield indicate that the group B dikes in the southern Tobacco Root Mountains are part of the regional 780 Ma Gunbarrel magmatic event that extended for greater than 2400 km along the western margin of Laurentia. The origin of the magmatic event is not clear, but it may be related to a mantle plume and/or crustal extension accompanying or perhaps slightly predating initial breakup of the supercontinent Rodinia and development of the proto-Pacific Ocean. No evidence of ca. 1100 Ma mafic magmatism in this part of the northern Cordillera was found.

Proterozoic Mafic Dikes in Southwestern Montana



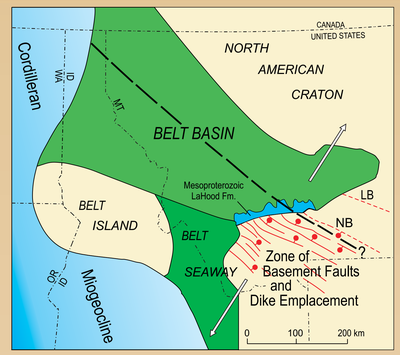
Modified from Schmidt and Garihan (1986)

Proterozoic mafic dikes are common in the basement-cored uplifts of the Laramide foreland province of Wyoming and Montana. In southwestern Montana, west- and northwest-striking dikes are found in, and parallel to subparallel, to a pervasive zone of Laramide-age (Late Cretaceous-early Tertiary) reverse or thrust faults that cut the Archean crystalline basement. These dikes are thought to have been emplaced parallel to normal faults that formed during northeast-southwest-directed extension accompanying development of the Helena embayment of the Mesoproterozoic (ca. 1470 to 1400 Ma) Belt-Purcell Basin (Harrison et al., 1974; Wooden et al., 1978; Schmidt and Garihan, 1986; Evans et al., 2000).

Geochemical analyses of dikes from the Ruby Range and southern Tobacco Root Mountains identified three distinct groups with Rb-Sr ages of 1455 ± 125 Ma (group A), 1120 ± 185 (group B), and 1130 ± 130 (group C) (Wooden et al., 1978). The 1450 Ma age is similar to dates from mafic sills that intrude sedimentary rocks of the Belt-Purcell Supergroups (Höy, 1989; Hunt, 1962; Zartman et al., 1982; Anderson and Davis, 1995; Sears et al., 1998), but the 1100 Ma age does not correlate with known magmatic events in the northern Cordillera. Geochronologic data from this study provides evidence for two widespread episodes of mafic magmatism along the western margin of the Laurentian craton at about 1450 Ma and 780 Ma. The 1450 Ma dikes appear to be related to extension accompanying development of the Mesoproterozoic Belt Basin, whereas the 780 Ma dikes appear to be related to a major episode of mafic magmatism along the western margin of Laurentia that may be related to the breakup of the supercontinent Rodinia.

NW-SE Extension During ca. 1450 Ma Mesoproterozoic Development of the Belt Basin

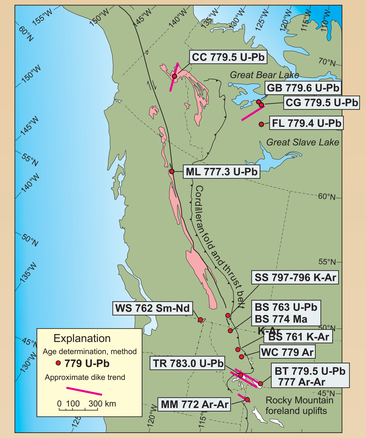
Mafic dikes in the southern Tobacco Root Mountains likely reflect NW-SE extension during development of the Mesoproterozoic Belt Basin and the isotopic dates from the dikes are identical to U-Pb dates from mafic dikes for voluminous mafic intrusions that are found with the sedimentary strata of the Belt Supergroup and in foreland structures to the SE (Anderson and Davis, 1995; Chamerlain and Frost, 1995). NW-Trending faults and fractures that formed at this time have controlled and localized subsequent tectonic and intrusive activity including emplacement of the 780 Ma group B mafic dikes.



Modified from Schmidt and Garihan (1986)

Areal Extent of the 780 Ma Gunbarrel Magmatic Event

The Gunbarrel magmatic event is a regional magmatic event that extends for > 2500 km along the western margin of the Neoproterozoic Laurentian craton. U-Pb baddeleyite analyses for eight intrusions from seven localities from the northern Canadian Shield to northwestern Wyoming-southwestern Montana are statisically indistinguishable and yield a composite U-Pb concordia age for this event of 780.3 ± 1.4 Ma (95% confidence level). A number of other dates from mafic dikes and sills have provided further delineation of this event. The mafic mafmatism of the Gunbarrel event represents the largest mafic dike swarm yet identified along the Neoproterozoic margin of Laurentia. The origin of the mafic magmatism is not clear, but it may be due to crustal extension accompanying initial breakup of the supercontinent Rodinia and development of the proto-Pacific Ocean.



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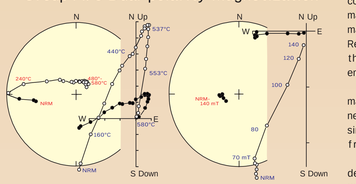
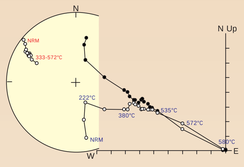
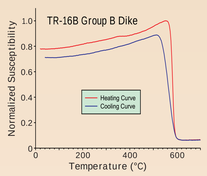
Paleomagnetic Data from Mafic Dikes in the Southern Tobacco Root Mtns, MT

Group A/C Dual-polarity Magnetization



Group B Magnetization

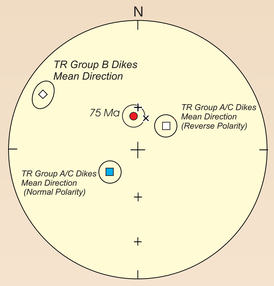




Paleomgnetic results from the Tobacco Root dikes yield distinct two distinc magnetizations that correspond to the geochemical groups. Both magnetizations are distinctly different from magnetiztions of more recent (Late Cretaceous-Recent) and probably represent primary thermoremanent magnetizations acquired during dike emplacement.

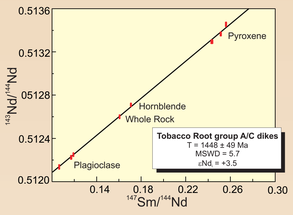
Group A dikes have a well-defiend dual polarity magnetization of NE (SW) - declination and moderate negative (positive) inclination. This magnetization is similar to Mesoproterozoic (ca. 1450-1400 Ma) poles from elsewhere in North America.

Group B dikes yield a magnetization of northwest declination and shallow negative inclination. This magnetization yields a pole that is identical to poles from Neoproterozoic dikes elsewhere in the northern Cordillera, including dikes and sills of the Gunbarrel magmatic event.

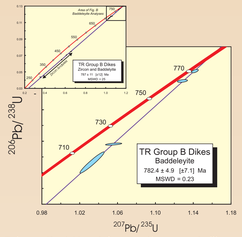


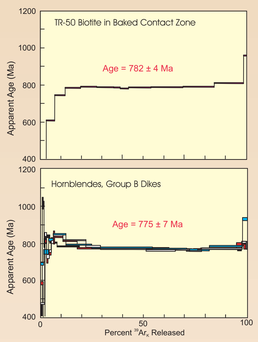
Geochronologic Data

Sm-Nd Age for ca. 1450 Ma Group A/C Dikes



U-Pb and $^{40}Ar/^{39}Ar$ Dates for ca. 780 Ma Group B Dikes

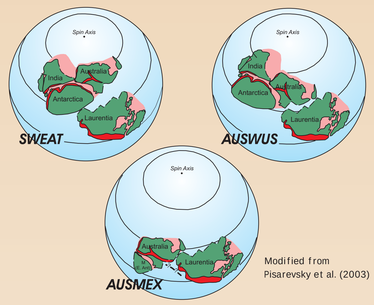




Isotopic dates were obtained from from dikes in the southern Tobacco Root Mountains. For the group A dikes, a composite mineral Sm-Nd date of 1447 ± 49 Ma was obtained, which we consider to represent the emplacement age of the group A dikes. This age is similar to U-Pb dates from mafic sills exposed to the northwest in the Mesoproterozoic Belt Basin (Anderson and Davis, 1995; and references therein) and to dikes exposed to the southeast in the Wind River Range (Chamberlain and Frost, 1995).

The group B dikes were dated by both U-Pb and $^{40}Ar/^{39}Ar$ methods. The best estimate for the emplacement age for these dikes is given by baddeleyite which gives 782.4 ± 4.9 Ma. $^{40}Ar/^{39}Ar$ dates from primary hornblende and a reset biotite from the baked contact zone give essentially identical ages of 775 and 782 Ma, respectively. The ca. 780 Ma age for these dikes is similar to dates from NW-trending dikes elsewhere in Montana and Wyoming and to some mafic sills and dikes that intrude the Belt Supergroup. These dikes are part of the regional 780 Ma Gunbarrel magmatic event that extends from northwestern Wyoming to the Arctic Ocean and which probably represents early extension and magmatism associated with the breakup of Rodinia.

Proposed Rodinia Plate Reconstructions



Modified from Pisarevsky et al. (2003)

Precisely dated mafic dikes swarms and magmatic events that have affected the western margin of Laurentia, including the ca. 1450 Ma Mesoproterozoic Belt Supergroup sills and dikes, the ca. 1080-1100 Ma mafic sills of the central Arizona diabase province, the 780 Ma Gunbarrel dikes and sills, and the 723 Mackenzie dikes potentially provide critical piercing points that can be used to help constrain paleocontinental reconstructions for the supercontinent Rodinia. Ideally, regionally extensive mafic magmatic events should have counterparts on continental blocks that have been since been dispersed by plate tectonic processes. Precise isotopic dating of such dikes and sills, in combination with the determination of paleomagnetic poles, should greatly improve our understanding of Neoproterozoic paleogeography.

Conclusions

Geochronologic data from mafic dikes in the southern Tobacco Root Mountains of southwestern Montana provide evidence for two discrete mafic magmatic episodes characterized by the emplacement of northwest-striking dike swarms. A Sm-Nd mineral isochron from geochemical group A/C dikes yields an age of 1448 ± 49 Ma consistent with the whole rock Rb-Sr isochron reported by Wooden et al (1978). Mafic magmatism at ca. 1450 Ma was likely related to extension during development of the nearby Mesoproterozoic Belt Basin. U-Pb dates from the southern Tobacco Root Mountains group B dikes document the presence of a Neoproterozoic magmatic event at 782.4 ± 4.9 Ma. These dikes were emplaced parallel to subparallel to the ca. 1448 Ma dikes of group A/C. and were coeval to northwest-trending dikes in the other foreland uplifts of the Wyoming province and some of the mafic sills that intrude the Belt Supergroup. Regionally, these dikes were part of a major episode of essentially synchronous 780 Ma mafic magmatism called the Gunbarrel magmatic event that extended for > 2400 km along the western margin of Laurentia. The group B dikes may have been part of an ancient mantle plume related to the breakup of the Rodinian supercontinent, similar to that inferred for the Jurassic break-up of Pangea (Marzoli et al., 1999). No evidence was found for a mafic event at 1100 Ma along the western margin of the Wyoming craton, as had been proposed from earlier Rb-Sr dating of mafic dikes in the southern Tobacco Root Mountains of southwestern Montana.

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