

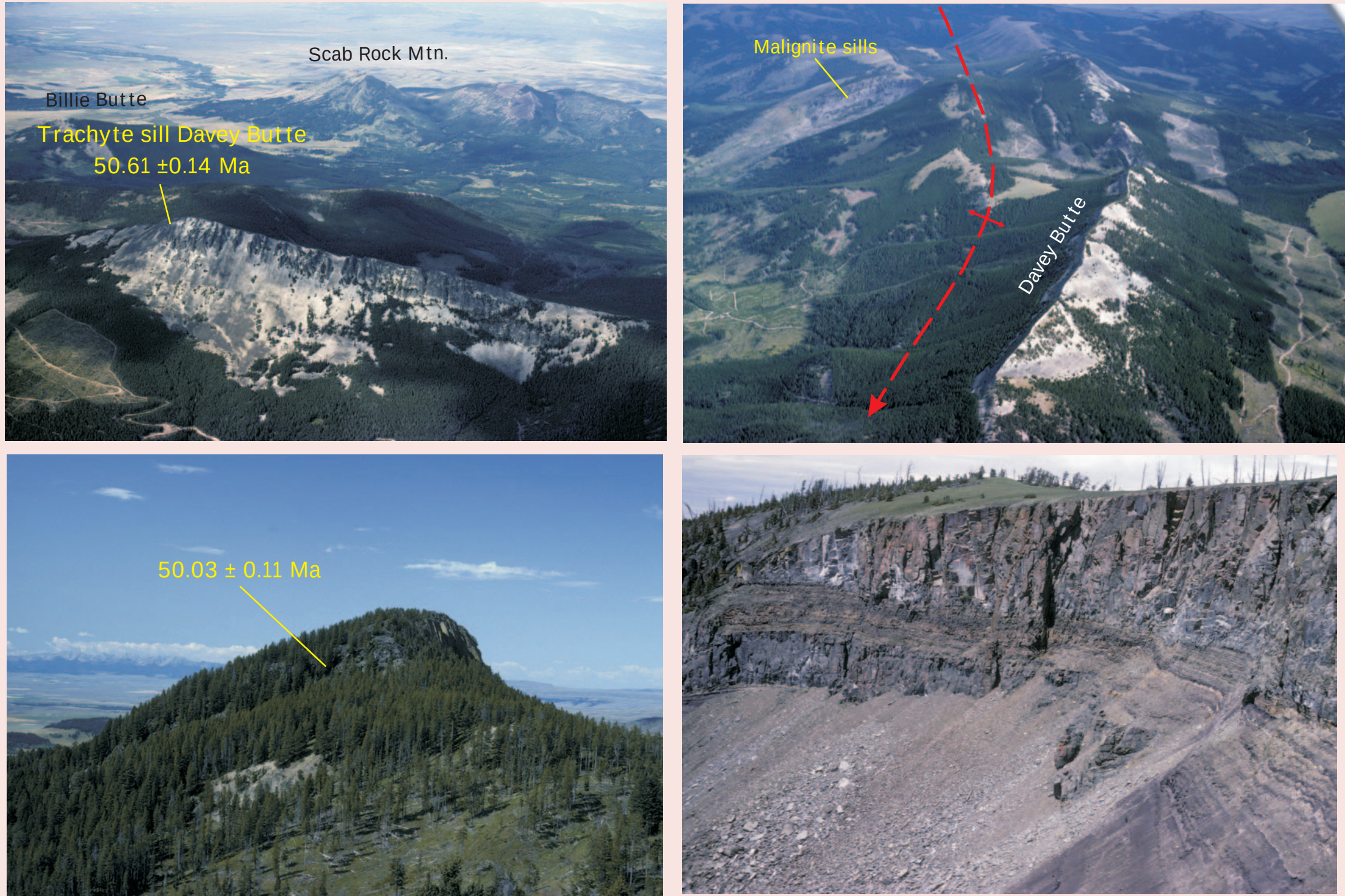
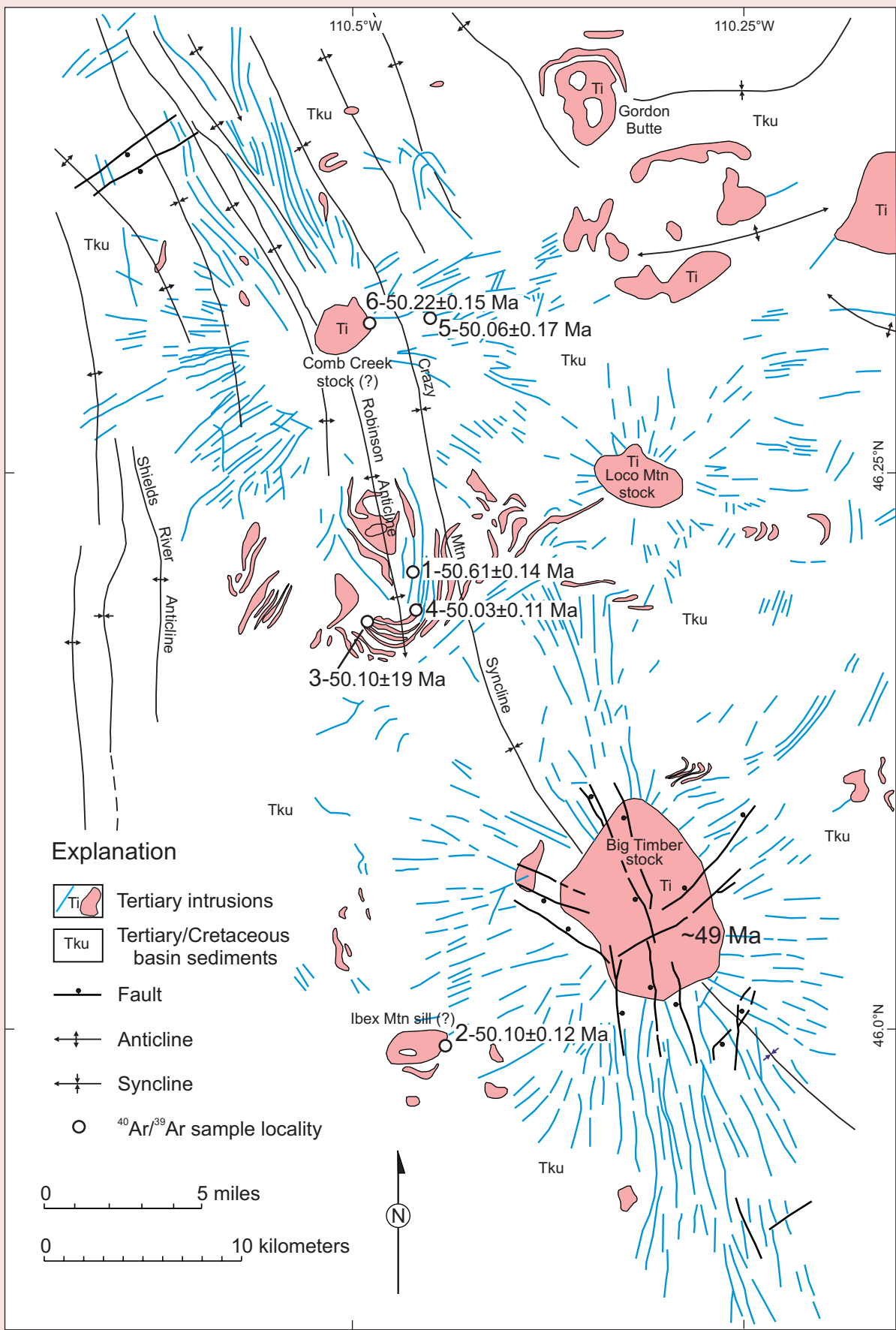
New ⁴⁰Ar/³⁹Ar dates from alkaline intrusions in the northern Crazy Mountains, Montana: Implications for the timing and duration of alkaline magmatism in the Central Montana Alkalic Province

Stephen S. Harlan

Dept. of Environmental Sciences and Policy, George Mason University, Fairfax, VA 22030-4444, U.S.A.; sharlan@gmu.edu

Crazy Mountains Intrusions

Photographs of Robinson Anticline Intrusive Complex



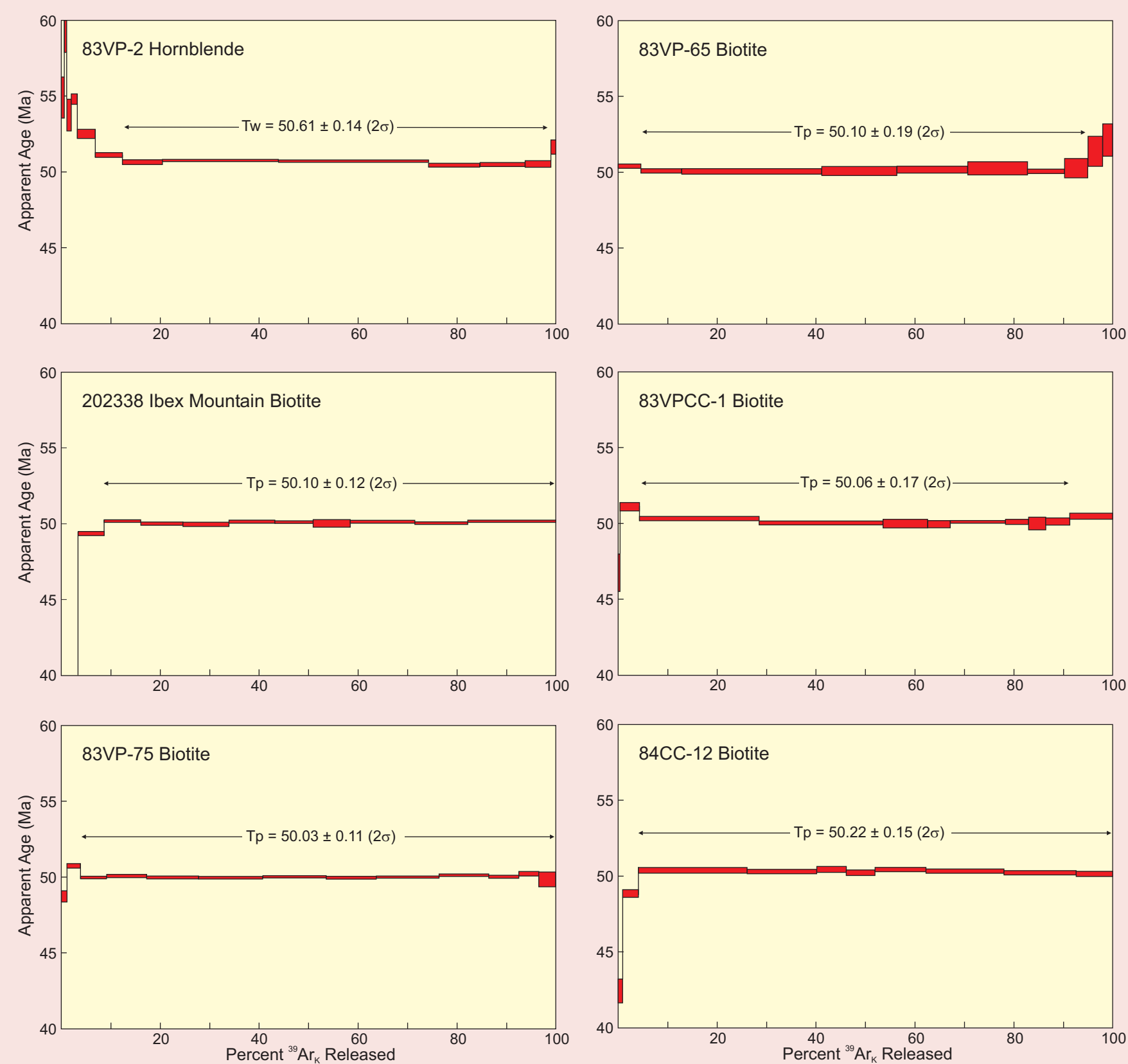
Top: Aerial views of south plunging nose of Robinson anticline. Prominent light gray intrusion is a trachyte sill that forms part of the east limb of the fold. Bottom left: Columnar-jointed mafic nepheline syenite sill in south plunging nose of Robinson Anticline. Bottom Right: Mafic nepheline syenite sills cutting Tertiary sedimentary rocks in the west flank of the anticline.

INTRODUCTION

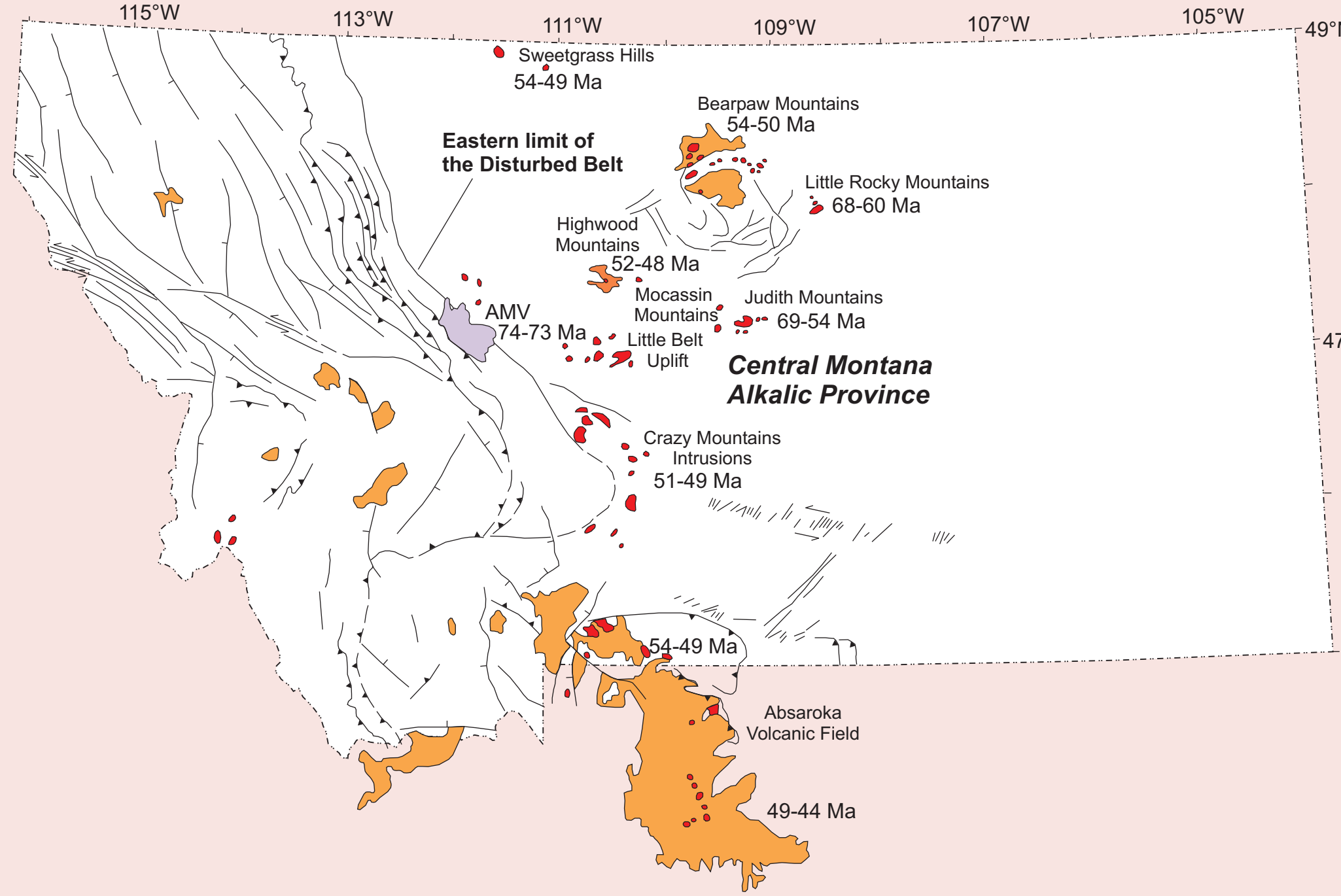
The Crazy Mountains Basin is a structural and physiographic basin located along the eastern margin of the Cordilleran fold and thrust belt in west-central Montana. The basin originated as a fore deep located east of the main Cordilleran orogenic belt (Dickinson et al., 1988). The original geometry of the basin has been subsequently modified and partitioned by the encroachment of thin-skinned, decollement-style folds and thrust faults of the Montana Disturbed Belt (Woodward, 1981; Garret, 1972) and by basement-involved folds and thrust faults of the Rocky Mountain foreland province (Schmidt and Garihan, 1983; Gries, 1983).

The basin fill consists of Upper Cretaceousmiddle Paleocene (?) clastic and volcanoclastic sediments of the Livingston Group and Fort Union Formation (Roberts, 1972). In the approximate center of the basin, the sedimentary strata were intruded by subalkaline and alkaline stocks, sills, and dikes. Temporally, these intrusions are part of the Central Montana Alkalic Province, a group of Tertiary intrusive and volcanic rocks that form isolated uplifts east of the main Rocky Mountain front (Chadwick, 1972). Within the Crazy Mountains, igneous rocks representing two distinct magma series are present (Dudas et al., 1987; Dudas, 1991; du Bray and Harlan, 1996): (1) sodium-rich, strongly alkaline mafic syenites (also known as malignites), syenites, and trachytes of the Comb Creek stock (?) and dike swarm, the Gordon Butte-Elk Mountain-Coffin Butte sills, the Ibex Mountain sill, and the Robinson anticline intrusive complex (Simms, 1966; Larson and Simms, 1972; Fink, 1975; Emmart, 1985; Harlan et al., 1988; Dudas, 1991) and (2) subalkaline rocks consisting of potassium-rich basalts, diorites, and granodiorites of the Big Timber and Loco Mountain stocks and associated dike swarms (Tappe, 1966; Larsen and Simms, 1972; Starmer, 1972; du Bray and Harlan, 1996). With the exception of the sill at Ibex Mountain, the strongly alkaline rocks are largely restricted to the northern Crazy Mountains, whereas the subalkaline rocks are found mostly in the southern Crazy Mountains. The strongly alkaline rocks intrude the easternmost folds of the Montana Disturbed Belt and the arcuate and concordant nature of some sills with fold structure has suggested that at least some of the igneous activity may have preceded folding (Simms, 1966; Harlan et al., 1988). Paleomagnetic and structural analysis, however, demonstrated that intrusion of the sills in the Robinson anticline intrusive complex post-dated thin-skinned fold and thrust belt deformation (Harlan et al., 1988). Geochronologic data from the Crazy Mountains intrusions indicate that they were emplaced during the Eocene at ~52 to 48 Ma during the height of magmatic activity of the Challis magmatic flare-up (Harlan et al., 1988; Dudas, 1991). This paper presents new high-precision ⁴⁰Ar/³⁹Ar geochronologic data obtained from the strongly alkaline intrusions from the northern Crazy Mountains that complement previously published ⁴⁰Ar/³⁹Ar geochronologic data from the subalkaline Big Timber stock (du Bray and Harlan, 1996).

Geochronology of Alkaline Intrusions

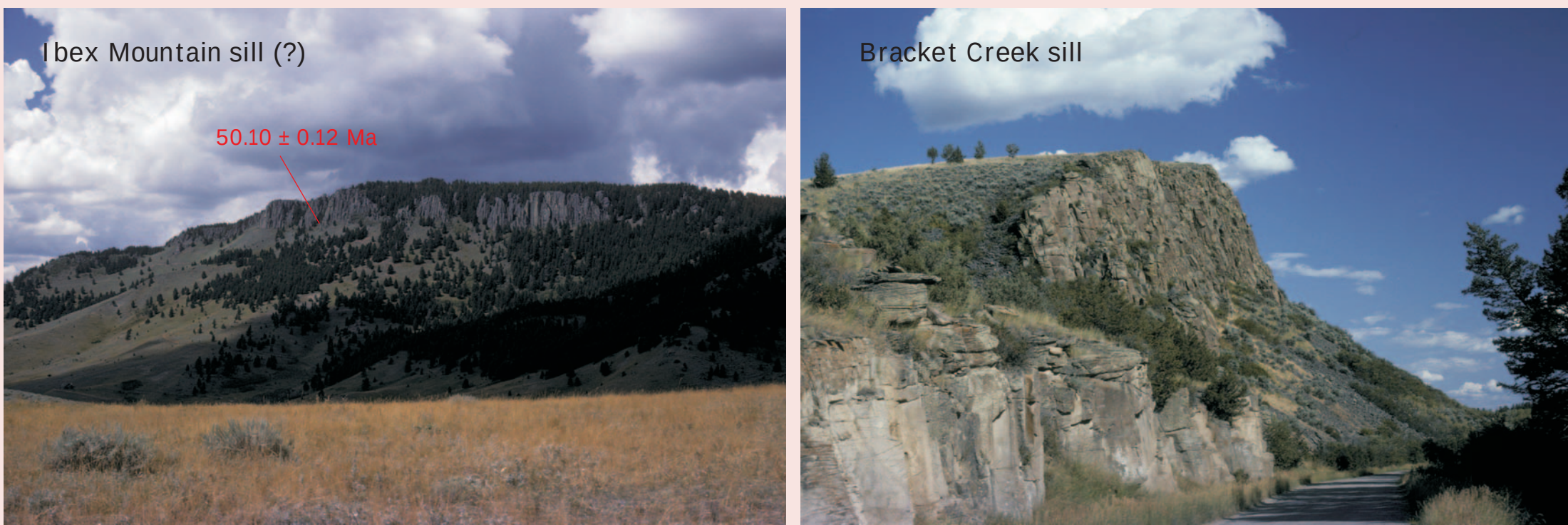


Regional Volanic and Intrusive Activity Associated with the Challis Magmatic Event



CONCLUSIONS

Isotopic dating of mineral separates from the strongly alkaline intrusive rocks from the Crazy Mountains yield well-defined age spectra and represent substantial improvement in our understanding of the intrusive history of this area. The new dates indicate emplacement of a trachyte sill at 50.61 Ma and that mafic and felsic nepheline syenites from five separate intrusions of mafic and felsic nepheline syenites were emplaced during a short period of time from 50.22 to 50.03 Ma. Because of the shallow nature of these intrusions, these dates represent the age of emplacement of the individual features. Overall, the geochronologic data from the Crazy Mountains indicate that the intrusions from the alkaline and subalkaline groups were emplaced at approximately the same time and may have spanned an interval of time on the order of 1 to 2 m.y.



REFERENCES

Armstrong, R. L., 1978. Cenozoic igneous activity of the U.S. Cordillera from lat. 42° to 49°N. Geological Society of America Memoir 152, p. 265-282.

Chadwick, R. A., 1972. Volcanism in Montana: Northwest Geology, v. 1, p. 120.

Chadwick, R. A., 1981. Chronology and structural setting of volcanism in southwestern and central Montana. In Tucker, T. E., Aram, R. B., Binkler, W. F., and Grabb, R. F., Jr., eds., Montana Geological Society field conference and symposium guidebook to Southwest Montana. Billings, Montana Geological Society, Guidebook, p. 301-310.

Dickinson, W. R., Hulse, M. A., Hayes, M. J., Janesick, S. U., Lardin, E. R., Molnar, W. A., and Oliver, M. D., 1988. Paleogeographic and paleotectonic setting of Laramide sedimentary basins in the central Rocky Mountain region. Geological Society of America Bulletin, v. 100, p. 1023-1039.

du Bray, E. A., and Harlan, S. S., 1996. The Eocene Big Timber stock, south-central Montana: Development of extensive compositional variation in an arc-related intrusion by side-wall crystallization and cumulate glomerocryst remixing. Geological Society of America Bulletin, v. 108, no. 11, p. 1404-1424.

Dudas, F. O., 1991. Geochemistry of igneous rocks from the Crazy Mountains, Montana, and tectonic models for the Montana Alkalic Province. Journal of Geophysical Research, v. 96, p. 32263-32277.

Dudas, F. O., Carlson, R. W., and Eggle, D. H., 1987. Regional Middle Proterozoic enrichment of the subcontinental mantle source of igneous rocks from central Montana. Geology, v. 15, p. 2225.

Emmert, L. A., 1985. Volatile transfer differentiation of the Gordon Butte magne, northern Crazy Mountains, Montana. (Master's Thesis). Missoula, University of Montana, 83 p.

Feeley, T. C. and Cosca, M. A., 2003. Time vs. composition trends of magmatism at Sunlight volcano, Absaroka volcanic province, Wyoming. Geological Society of America Bulletin, v. 115, p. 714-728.

Fink, R. A., 1975. The geology and igneous geology of the Comb Creek dike swarm, Crazy Mountains, Montana. (Master's thesis). Cincinnati, University of Cincinnati, 174 p.

Fleck, R. J., Sutter, J. F., and Elliott, D. H., 1977. Interpretation of discordant ⁴⁰Ar/³⁹Ar age-spectra of Mesozoic tholeiites from Antarctica. Geochimica et Cosmochimica Acta, v. 41, p. 1532.

Garret, H. L., 1972. Structural geology of the Crazy Mountains Basin, in Field Conference. Billings, Montana Geological Society, 21st Annual Field Conference Guidebook, p. 185-195.

Gries, R., 1983. North-south compression of Rocky Mountain foreland structures, in Lowell, J., ed., Rocky Mountains foreland basins and uplifts. Denver, Rocky Mountain Association of Geologists, Guidebook, p. 932.

Harlan, S. S., Geissman, J. W., Lagason, D. R., and Snee, L. W., 1988. Paleomagnetic and isotopic dating of thrust belt deformation along the eastern edge of the Helena salient, northern Crazy Mountains Basin, Montana. Geological Society of America Bulletin, v. 100, p. 4924-4929.

Harlan, S. S., Snee, L. W., Geissman, J. W., 1996. ⁴⁰Ar/³⁹Ar geochronology and paleomagnetism of Independence volcano, Absaroka Volcanic Supergroup, Bear Tooth Mountains, Montana. Canadian Journal of Earth Sciences, v. 33, p. 1648-1654.

Larsen, L. H., and Simms, F. E., 1972. Igneous geology of the Crazy Mountains, Montana: A report of work in progress, in Field Conference. Billings, Montana Geological Society, 21st Annual Field Conference Guidebook, p. 135-139.

Martin, R. F., and Dobson, S. W., 1979. Radiometric ages: Compilation B, U.S. Geological Survey. Isochron/West, no. 26, p. 332.

Martin, R. F., Wilkink, J. J., Keeler, W. R., and McNeill, H. H., 1973. Radiometric ages of intrusive rocks in the Little Belt Mountains, Montana. Geological Society of America Bulletin, v. 84, p. 1973-1986.

Martin, R. F., Harris, R. C., Jr., McNeill, H. H., Naefer, C. W., Zarman, R. E., and Lindsey, D. A., 1980. Late Cretaceous-Paleocene-Eocene igneous activity in north-central Montana: Isochron/West, no. 29, p. 525.

Roberts, A. E., 1972. Cretaceous and early Tertiary depositional and tectonic history of the Livingston area, southwestern Montana. U.S. Geological Survey Professional Paper 526-C, 119 p.

Schmidt, C. J., and Garihan, J. M., 1983. Laramide tectonic development of the Rocky Mountain foreland of southwestern Montana, in Lowell, J., and Gries, R., ed., Rocky Mountains foreland uplifts and basins. Denver, Rocky Mountain Association of Geologists, Guidebook, p. 271-294.

Simms, F. E., 1966. The igneous petrology, geochemistry, and structural geology of part of the northwestern Crazy Mountains, Montana. (Ph.D. dissertation). Cincinnati, Ohio, University of Cincinnati, 339 p.

Smedes, W. H., and Prottska, H. J., 1972. Stratigraphic framework of the Absaroka Volcanic Supergroup in Yellowstone National Park region. U.S. Geological Survey Professional Paper, 729-C, 33 pp.

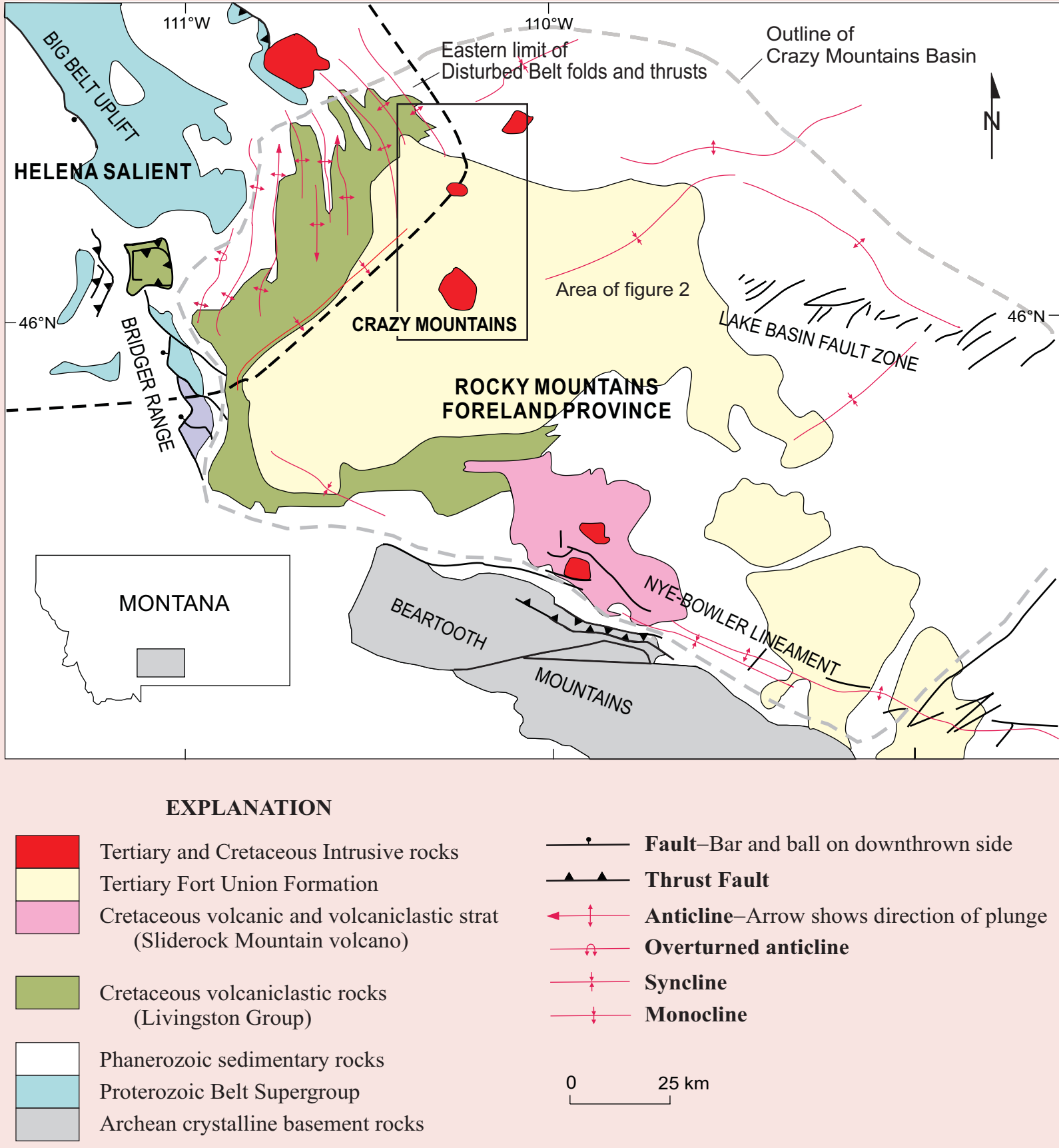
Starmer, R. J., 1972. The Big Timber dike swarm, Crazy Mountains, Montana. Distribution and chemistry: unpublished Ph.D. thesis, University of Cincinnati, Cincinnati, Ohio.

Tappe, J., 1966. The chemistry, petrology, and structure of the Big Timber igneous complex, Crazy Mountains, Montana. (Ph.D. dissertation). Cincinnati, University of Cincinnati, 177 p.

Taylor, R. L., Ashley, J. M., Chadwick, R. A., Custer, S. G., Lagason, D. R., Locke, W. W., II, Mogk, D. W., Schmitt, J. G., and Erickson, J. B., 1984. Geological map of Montana and Yellowstone National Park. Montana State University, Department of Earth Sciences.

Woodward, L. A., 1981. Tectonic framework of the Disturbed Belt of west-central Montana. American Association of Petroleum Geologists Bulletin, v. 65, p. 2193-2202.

Tectonic Map of the Crazy Mountains Basin



Photographs of the Subalkaline Big Timber Stock



Subalkaline rocks are found mostly in the southern Crazy Mountains, where they form stocks, sills, and dikes. The largest intrusion is the Big Timber stock (ca. 49 Ma), and its associated radial dike swarm. The Big Timber sock intrudes Upper Cretaceous-Middle Paleocene strata of the Fort Union Fromation near the approximate center of the basin. The photograph at left shows steeply dipping, intermediate composition dikes that cut the contact metamorphic aureole of the Big Timber stock.