Journal of Structural Geology, Vol. 14, No. 7, pp. 891 to 892, 1992
Printed in Great Britain

0191-8141/92 $05.00+0.00

The age of cleavage development in the Ross orogen, northern Victoria Land, Antarctica: evidence from $^{40}Ar/^{39}Ar$ whole-rock slate ages: Reply

THOMAS O. WRIGHT

National Science Foundation, Division of Earth Sciences, 1800 G Street, NW Washington, DC 20550, U.S.A.

and

R. D. DALLMEYER

Department of Geology, University of Georgia, Athens, GA 30602, U.S.A.

(*Received* 6 *January* 1992; *accepted* 3 *April* 1992)

FINDLAY makes several comments and criticisms of our description of the local geology near Handler Ridge and the Lensen Glacier. He questions some temporal, spatial, textural and kinematic observations and interpretations, and suggests an importance to our paper at variance with our conclusions. We will discuss the substantive issues applying to our paper, but will avoid extensive accounts of early tectonic models because, as pointed out by Bradshaw *et al.* (1985), rapid progress in the last decade has demonstrated that many early interpretations of the history of northern Victoria Land (NVL) are now inadequate and their replacements are still evolving.

Much of the ambiguity referred to by Findlay results from how terranes in NVL were defined and subsequently modified and from the nature of the faults separating the various terranes. An abrupt change in lithology, regionally traceable across NVL, led to the early distinction between the Bowers Group (Sturm & Carryer 1970) and the Robertson Bay Group to the east, and to the naming of the Leap Year Fault (LYF) suspected of separating the two (Dow & Neall 1974). This interpreted fault underlies glaciers and snowfields along its entire length except for a few possible exceptions. Stump *et al.* (1983) and Jordan *et al.* (1984) described locally exposed vertical shear zones along the projected LYF which are consistent with the generally straight map trace of the LYF as shown on regional maps (cf. GANOV EX Team 1981). Thus the LYF is a poorly-exposed probably high-angle boundary between the originally-defined Bowers and Robertson Bay groups that has come to represent the effective terrane boundary fault between the Bowers and Robertson Bay terranes.

Several observations complicate this simplified model; in particular, exposure of schistose rocks in several places along the west margin of the Robertson Bay Terrane adjacent to the LYF, and, in the Handler Ridge area, the presence of thrusts and reverse faults locally placing strained Bowers Supergroup rocks over the schistose rocks and/or the Robertson Bay Group rocks east of the traditional placement of the LYF. The schistose rocks have been mentioned since the early studies (e.g. Crowder 1968) and Findlay & Field (1983) describe them in the Millen Range. Bradshaw *et al.* (1985) reported that the 'Millen Schists' appear to represent zones of higher strain rather than a discrete rock unit and include both Robertson Bay and Bowers lithologies as protoliths. Despite this, Findlay (1986) elevated the schistose rocks to Terrane status (Millen Terrane), showing them as a discontinuous belt extending across NVL. Findlay (this discussion) still considers the 'Millen Terrane' as distinct and in fault contact with the Bowers Terrane to the southwest and the Robertson Bay Terrane to the northeast. However, he acknowledges that lithologies forming the Millen Terrane may correlate with lithologic elements in both the Bowers and Robertson Bay terranes.

For the terrane status to be appropriate for the schistose rocks, boundary faults must exist and the Millen Terrane should possess a history different from the adjacent terranes. None of these are unambiguously required by presently known field relationships. The traditional LYF in the snowfield shown on Findlay's fig. 1 is unconstrained except for the presence of isolated nunitaks exposing metasedimentary rocks. Some nunitaks appear to be composd of Bowers Terrane metasediments while others resemble lithologies in the Robertson Bay Terrane. These relationships do not require a fault (Bradshaw *et al.* 1985). Findlay (fig. 2 of his Discussion) shows a fault (Handler Fault) separating the schistose rocks from the Robertson Bay rocks to the east. This is an unwarranted correlation and extrapolation between two locally exposed faults—one at the southwestern end of Handler Ridge (Wright & Brodie 1987) and one reported by Findlay & Field (1983) on the ridge northeast of Turret Ridge. These do juxtapose different rocks, but more importantly, no faults have

been observed along the intervening ridges as shown on Findlay's map. Detailed work along these ridges (Bradshaw *et al.* 1985, Wright unpublished data) indicate a gradual eastward decrease in deformation from 'schist' to the Handler Formation of the Robertson Bay Group.

We feel the concept of a separate 'Millen Terrane' has little merit, and that in the area where our samples for $^{40}Ar/^{39}Ar$ were collected, the Bowers Terrane comprises a hanging wall structurally over the Robertson Bay Terrane along a well-exposed thrust (variously named Crosscut Peak Thrust, Millen Thrust and labeled LYF; Wright & Dallmeyer 1991, fig. 2). As Findlay points out, the distinction between the LYF as a regional terrane boundary and the local juxtaposition by thrusting in this area was incompletely presented by us. We consider the small exposure of thrust rocks located along the southwest end of Handler Ridge (Handler Thrust) to be only a minor splay within the regional fault zone and was therefore not shown on our generalized location map. The fault on Turret Ridge does not require significant offset and was similarly omitted. Schistose rocks occur both above and below fault planes and were clearly derived from adjacent lithologic units. Kinematic indicators observed at several locations within the main Millen fault zone consistently suggest west over east transport. Similar relationships were observed within the reverse fault zone mapped on Handler Ridge. Fabric elements which define a fault-related schistosity (S_2) overprinted the previous regional cleavage (S_1) which appears to have formed at approximately 500 Ma. Because formation of the S_2 cleavage did not involve growth of new micas, it has not been possible to date the associated thrusting by $^{40}Ar/^{39}Ar$ techniques.

By contrast, Findlay concludes that there were two distinct generations of thrusting. One of them occurred syn-S_1 at 500 Ma. He contends the other may have occurred later at 417 Ma (his 'Handler event'). Of Findlay's two age assignments, the 417 Ma for the 'Handler Event' is the more speculative. This age assignment was based on his interpretation of a 420 ± 17 Ma conventional K–Ar age repoted by Adams & Kreuzer (1984) for low-K paragonite concentrate separated from a shear plane which cuts Lanterman Metamorphic rocks at Husky Pass, Lanterman Range. Adams & Kreuzer (1984) reported a conventional K–Ar age of 480 ± 4 Ma for muscovite from a 'late' quartz vein from the *same* exposure which is in the Wilson Terrane and >100 km from the Handler Ridge area. The correlation made by Findlay between the "reverse fault along the Bowers–Wilson Terrane boundary at [sic.] 417 Ma" is not therefore compelling to us. In view of the local and regional uncertainties, Findlay's speculations on correlations to Siluro–Devonian structural events in the Lachlan Fold Belt of eastern Australia seem unwarranted to us.

In summary, we conclude the following.

(1) We see no reason to alter our earlier conclusions.

(2) The discussion of the terrane boundary fault(s) was confusing and their origins, local names and correlations needed clarification.

(3) The concept of a separate 'Millen Terrane' is no longer useful or valid and should be discarded.

(4) We consider there is insufficient evidence for a Siluro–Devonian event in NVL.

REFERENCES

Adams, C. J. & Kreuzer, H. 1984. Potassium–argon age studies of slates and phyllites from the Bowers and Robertson Bay Terranes, north Victoria Land, Antarctica. *Geol. Jb.* **B60**, 265–288.

Bradshaw, J. D., Begg, J. C., Buggisch, W., Brodie, C. Tessensohn, F. & Wright, T. O. 1985. New data on Paleozoic stratigraphy and structure in north Victorian Land. *N.Z. Antarctic Rec.* **6**(3), 1–6.

Crowder, D. F. 1968. Geology of part of north Victoria Land. *Prof. Pap. U.S. geol. Surv.* **600D**, D95–D107.

Dow, J. A. S. & Neall, V. E. 1974. Geology of the lower Rennick Glacier, northern Victoria land, Antarctica. *N.Z. J. Geol. Geophys.* **17**, 659–714.

Findlay, R. H. 1986. Structural geology of the Robertson Bay and Millen Terranes, northern Victoria Land, Antarctica. In: *Geological Investigations in Northern Victoria Land* (edited by Stump, E.). *Am. Geophys. Un., Antarctic Res. Ser.* **46**, 91–114.

Findlay, R. H. & Field, B. D. 1983. Tectonic significance of deformations affecting the Robertson Bay Group and associated rocks, northern Victoria Land, Antarctica. In: *Antarctic Earth Science* (edited by Oliver, R. L., James, P. R. & Jago, J. B.). Australian Academy of Science, Canberra, 107–112.

GANOVEX Team 1987. Geological map of north Victoria Land, Antarctica, 1,500,000—Explanatory Notes. In: *German Antarctic North Victoria Land Expedition* 1982/1983 (edited by Tessensohn, F. & Roland, N. W.). *Geol. Jb.* **66**, 7–79.

Jordan, H., Findlay, R., Mortimer, G., Schmidt-Thomé, M., Crawford, A. & Muller, P. 1984. Geology of the north Victoria Land, Antarctica. *Geol. Jb.* **B60**, 57–81.

Stump, E., Laird, M. G., Bradshaw, J. D., Holloway, J. R., Borg, S. & Lapham, K. E. 1983. Bowers graben and associated tectonic features cross northern Victoria Land, Antarctica. *Nature* **304**, 334–336.

Sturm, A. G. & Carryer, S. J. 1970. Geology of the region between the Matusevitch and Tucker glaciers, N. Victoria Land, Antarctica. *N.Z. J. Geol. Geophys.* **13**, 408–435.

Wright, T. O. & Brodie, C. 1987. The Handler Formation, a new unit of the Robertson Bay Group, north Victoria Land, Antarctica. In: *Gondwana Six: Structure, Tectonics and Geophysics* (edited by McKenzie, G.). *Am. Geophys. Un. Geophys. Monogr.* **40**, 25–30.

Wright, T. O. & Dallmeyer, R. D. 1991. The age of cleavage development in the Ross orogen, Northern Victoria Land, Antarctica: evidence from $^{40}Ar/^{39}Ar$ whole-rock slate ages. *J. Struct. Geol.* **13**, 677–690.