A new insight into Lewisian chronology

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Introduction

In the central region of the Lewisian Complex of NW Scotland the Badcallian granulite facies metamorphism caused massive depletion of U and Th relative to Pb (Moorbath *et al*, 1969) and obliterated the protolith age record of whole-rock isotopic systems. Here, a combined SHRIMP and cathodoluminescence (CL) study has revealed hitherto unrecognized complexity in zircons from the type localities of the Scourian granulites. Using CL images to guide selection of probe sites we have, for the first time, obtained direct protolith ages for Lewisian gneisses of up to 2950 Ma. The previously held age estimate of 2660 ± 20 Ma for the Badcallian event, which is based on conventional bulk zircon data (Pidgeon & Bowes, 1972), is shown by the new ion-probe results to be a spurious mixed age. The true age of metamorphism appears to be *c.* 2500 Ma.

Granulite zircons

Pidgeon & Bowes (1972) described clear, structureless, rounded zircons from localities at Upper Badcall Bay and Kylestrome and considered them to be wholly metamorphically grown. Upon recollection we discovered, in addition to rounded multifaceted zircon grains, copious prismatic grains with pyramidal terminations. In plane and reflected light many of these grains looked clear and structureless also. However, investigation by CL revealed exceedingly complex internal structures in both morphological groups. Many grains have fine-scale zones resembling igneous oscillatory zoning, while others contain remains of zones overprinted by areas of homogeneous structure. Generally, the zircons are very poor in U and Th, but the homogeneous overgrowths are particularly depleted in these elements, suggesting an association with the Badcallian depletion episode. The oscillatory zoned material we interpret as remnants of zircons that crystallized in the tonalitic protoliths of the granulites.

SHRIMP data

In their study, Pidgeon & Bowes (1972) obtained discordant Pb/U ages which they projected to a visually estimated concordia intercept age of 2660 ± 20 Ma. The alignments of the two data sets were considered to reflect Laxfordian and Caledonian disturbances. The ion-probe data reveal no such alignments. Our data from both samples, featuring numerous analyses of the prismatic grains, scatter along the concordia curve from *c.* 2500 Ma to a maximum age of *c.* 2950 Ma. Our interpretation is that the protoliths of both studied gneisses crystallized ca 2950 Ma ago, and that the original igneous zircons suffered severe recrystallization, differential Pb loss and growth of U-depleted rims at *c.* 2500 Ma in an episode which we equate with the peak of Badcallian granulite facies metamorphism. These results corroborate the recent single crystal and intragrain study of Lewisian zircons by Corfu *et al.*, (1993) who found evidence for partial Pb loss and growth of new zircon at 2490–2480 Ma in their samples. However, the oldest ages detected by Corfu *et al.*, at *c.* 2710 Ma, are much lower than those reported in this study, which can be attributed to their larger analytical scale, smaller data set, and the limitations of sample selection based on optical examination alone.

Scourie ultramafics

We have also analysed zircons from a metatonalite sheet cross-cutting ultramafic gneisses at First Inlet, Scourie, that were the subject of an isotopic study by Cohen *et al.*, (1991). This sheet contains partially retrogressed orthopyroxene, so its emplacement clearly predates the Badcallian event. The zircons from the sheet primarily were rounded low-U grains, similar to those in the two samples discussed above, and they yielded the exact same range of isotopic compositions, again implying a protolith age of *c.* 2950 Ma and disturbance at *c.* 2500 Ma. Therefore, the interpretation of Cohen *et al.*, (1991) that the mafic and ultramafic gneisses at this locality

represent post-tonalite additions to the crust appears to have been a mistaken one. Rather they could represent fragments of early supracrustal sequences that were disrupted by the intrusive tonalites.

Gneisses at Laxford Brae

A sample of granodioritic gneiss was also collected from the roadcutting at Laxford Brae, part of the northern block which, unlike the Scourian gneisses, never reached granulite facies. The zircons in this sample do not show the recrystallization features or severe U depletion of the granulite zircons. Isotopically, they show less disturbance at *c.* 2500 Ma, but some high-U parts have responded to more recent events with major losses of Pb. A maximum age of *c.* 2850 Ma was obtained, with the exception of one old core recording an age of *c.* 3400 Ma, the oldest age yet recorded from the Lewisian complex. These differences with respect to the higher grade gneisses analyzed from the central region indicate that the Laxford sample belongs to a distinct package of rocks.

Implications for other isotope studies

Modelling of Nd isotopic evolution in the Lewisian has been hampered by the widely assumed crustal differentiation age of *c.* 2700 Ma for these rocks. (cf. Cohen *et al.*, 1991). When recalculated to 2950 Ma, most of the analysed gneisses give initial εNd values of between +3 and +5. Whole-rock Sm-Nd systems in the Lewisian were severely disturbed by the *c.* 2500 Ma metamorphism. An early Sm-Nd isochron age of 2920±50 Ma (Hamilton *et al.*, 1979) is fortuitously similar to our indicated 2950 Ma protolith age as it incorporated regionally sampled basic and felsic gneisses which undoubtedly were not cogenetic. Other more carefully selected suites have yielded less perfect isochron fits and younger apparent ages (Whitehouse 1988; Cohen *et al.*, 1991). In the whole-rock Pb-Pb system also there is considerable scatter beyond analytical uncertainty in the isochrons derived from these rocks (Moorbath *et al.*, 1969; Chapman & Moorbath 1977; Whitehouse 1989). In the light of the new zircon data presented here the *c.* 2490 Ma Sm-Nd mineral isochron ages obtained by Humphries & Cliff (1982) on Scourian peak granulite assemblages can be reinterpreted to represent not the time of closure of the system some time after the peak of metamorphism as suggested by the authors but the approximate time of peak metamorphism itself.

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