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U-Pb zircon age of the metavolcanic rocks of Fisher Massif (Prince Charles Mountains, East Antarctica)

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Abstract: Fisher Massif is believed to represent less metamorphosed portions of an extensive Proterozoic mobile belt, and is composed of metavolcanic rocks of different compositions and numerous intrusive bodies. U-Pb dating of six zircon fractions recovered from metavolcanic rocks of intermediate to acidic compositions defines growth time at *c.*1300 Ma with prominent Pb losses at 364 Ma and in recent time. Grain morphologies do not provide unequivocal genetic evidence, but an igneous origin for the grains studied is the most probable. The dates obtained probably reflect igneous activity be co-eval with mafic dyke emplacement event elsewhere in ancient East Antarctic cratonic blocks.

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Introduction

Fisher Massif is situated in the central part of the Prince Charles Mountains (PCM) which may be broadly subdivided into two major tectonic provinces: an Archaean cratonic block south of latitude 73°S and a Proterozoic mobile belt to the north (Tingey 1982, Kamenev *et al.* 1993). Kamenev & Krasnikov (1991) considered the cratonic block a granite-greenstone (Rucker) terrane. It is composed of Archaean (Kovach & Beliatsky 1991, Munskgaard *et al.* 1992), mainly amphibolite facies rocks of tonalite to granite compositions, tectonically interleaved with mafic to ultramafic volcanic and sedimentary rocks, metamorphosed under greenshist to lower amphibolite facies conditions. The relationships between the mafic metavolcanic rocks and granite-gneisses, and the age of the former are poorly known.

The Proterozoic, Circum East Antarctic Mobile Belt or Wegener-Mawson Mobile Belt (Kamenev 1993) occupies most of the outcrop area in an extensive terrain between Dronning Maud Land and Queen Mary Land (Bunger Hills) "tying together" ancient cratonic blocks (Enderby Land, Vestfold Hills, Rucker terrane). The Wegener-Mawson Mobile Belt in the PCM is formed mostly of 800–1000 Ma granulite to upper amphibolite facies felsic to mafic orthogneisses and metasedimentary rocks (Tingey 1982, Hensen *et al.* 1992). Thrust tectonics define the main structural features of both the Rucker Terrane and the Wegener-Mawson Mobile Belt. The Fisher Massif (FM) lies within the southern part of the Wegener-Mawson Mobile Belt and represents the less metamorphosed portions of it. The age and origin of the FM metavolcanic rocks are poorly known and are therefore important in constraining further the geological history of this part of the East Antarctic Shield. This paper presents new geological and isotopic data for these rocks.

Geological setting

Fisher Massif is an isolated uplifted highland block some 8–12 km wide and 32 km long extending NE–SW (Fig.1). FM is composed of metavolcanic and minor meta-tuffaceous rocks intruded by plutonic bodies of different compositions (gabbro, diorites, plagiogranites, as well as granodiorites and I and S-type granites (Mikhalsky 1993)). The age of granodiorites has been determined as 870 Ma (Krasnikov & Fedorov 1992). Volcanic rocks were metamorphosed under epidote-amphibolite facies conditions, and most of intrusive rocks are also metamorphosed; thus no primary ferro-magnesian minerals survived, although relic magmatic textures are commonly present. There are dykes of metagabbro-dolerite, dacite and trachydolerite.

Metavolcanic rocks constitute at least a half of the FM, being best exposed in the south-eastern cliffs about 400 m high. The rocks dip steeply to the NNW or NW at 50–80°, although the bedding dips more gently (25–50°) near the southern extremity of the area. The total thickness of the strata exceeds 3300 m and may be subdivided into four "sequences" on the basis of bulk composition. Sequence 1, about 1100 m thick, comprises metatuffaceous K-rich rocks with minor lava flows of intermediate to acidic composition. Metavolcanic rocks form lava flows or tuffaceous beds 1–20 m thick with only one relatively thick (up to 200 m) andesitic tuffaceous member. In some localities thin upper flow zones show chilled textures suggesting overturned bedding. Sequence 2 consists of metabasaltic flows and metagabbro-dolerite sills totalling 600 m thick.

Sequence 3 consists of intermediate to acidic Na-rich metavolcanic rocks about 400–450 m thick. Sequence 4 is entirely basaltic; it is more than 550 m thick, and is faulted against sequence 1. Rocks of sequences 2–4 are intruded by numerous, slightly discordant, thin subvolcanic bodies

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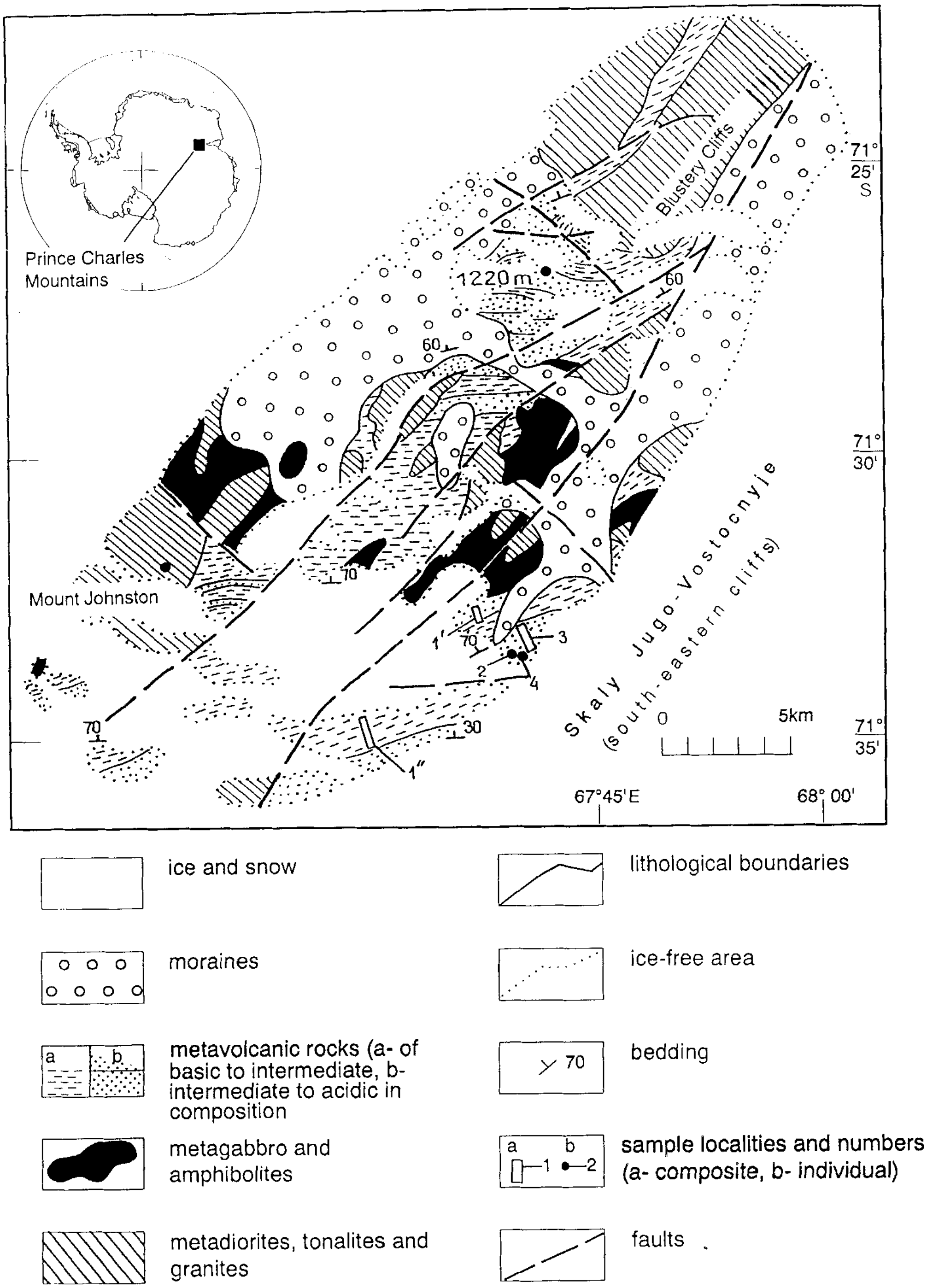

Fig. 1. Geological sketch of Fisher Massif (modified from Kamenev *et al.* 1993) to show the location of the dated samples.

totalling 700 m thick (probably dykes and sills); they are acidic with geochemical compositions corresponding to those of sequence 1. Therefore, it is likely that the whole succession is overturned. In the central highlands high-Al, plagiophyric metabasalts, basaltic andesites and metadolerites are widespread, together with acidic metavolcanic rocks. High-Al rocks seem to post-date the latter, but the relationships between high-Al rocks and other basic units were not observed.

Analytical techniques

Zircons were separated from samples of about 8–15 kg weight by crushing, sieving and conventional magnetic and heavy liquid procedures. Zircon populations were subdivided into different morphological types with the aid of a binocular magnifier. Aliquots of selected fractions were dissolved in sub-boiled distilled HF in teflon capsules within metal pressure bombs, held at 230°C for 1–2 weeks. The HF solutions were evaporated to dryness and samples were redissolved in

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Table I. Sample description.

Sample no.	Field no.	Sequence	Rocks included
1'	36712–30	3	Composite of 12 specimens of metaplagiodacite, -rhyodacites, -andesite.
1"	36712–30		Composite of nine specimens of subvolcanic rocks of intermediate to acidic composition cutting Sequence 4.
2	367126–17	1	Probably tuffaceous rhyodacite from a 3 m thick bed in the uppermost part of the section.
3	36719–40	1	Composite of 24 specimens of metadacite, metaandesite, and metariodacites representing the whole section (no tuffaceous rocks included).
4	36727–4	1	Metarhyodacite from a 0.7 m thick bed in the uppermost part of the section.

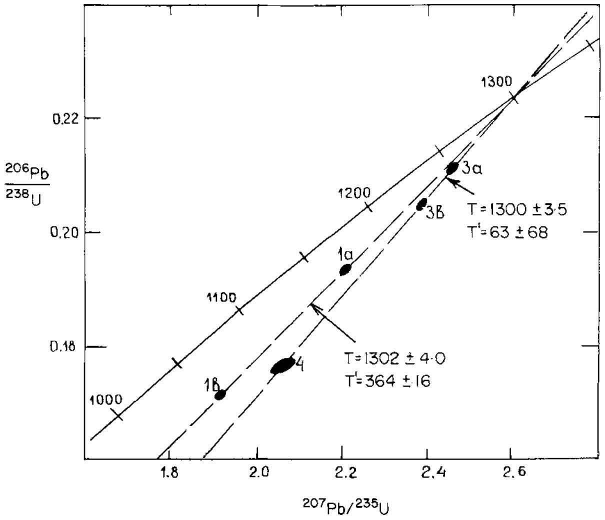

Fig. 2. U-Pb zircon data plot; sample numbers as in Table II.

3N HCl and heated overnight in the closed capsule in the oven at 190°C. After cooling, an aliquot of the solution was spiked with a mixed $^{208}Pb/^{235}U$ solution. U and Pb from the spiked and unspiked samples were separated using anion exchange techniques (Krogh 1973). Isotopic measurements were conducted on a Finnigan MAT-261 solid source mass-spectrometer at the Institute of Precambrian Geology and Geochronology (St. Petersburg). It was equipped with eight collectors running under static mode conditions using a single rhenium filament with silica gel-phosphoric acid activator for Pb, and a tantalum filament for U. The whole analytical blanks were not more than 0.1 ng for Pb and 0.005 ng for U during this study; the isotopic composition of the Pb used in correcting for common Pb was; $^{206}Pb/^{204}Pb$= 17.94, $^{207}Pb/^{204}Pb$= 15.32, $^{208}Pb/^{204}Pb$= 37.15, and for initial Pb using model lead composition of appropriate ages from Stacey & Kramers, 1975. Error calculation and U-Pb data plotting and regressions were performed using programs PbDAT and ISOPLOT (Ludwig 1990, 1991). Uncertainties on upper and lower intercept ages are stated at the 95% confidence level.

Zircon morphology and isotopic data

Four samples representing sequences 1 and 3 were collected at different localities (Fig. 1) for U-Pb zircon studies. The rock types sampled are listed in Table I. Abundant zircon grains were recovered from samples 1–3 but only a few from sample 4. In sample 1 two zircon generations were recognized: 1) short prismatic, and 2) highly elongated (needle-like) grains. Short prismatic grains are euhedral to subhedral, varying markedly from colourless to pink and from transparent to cloudy; cloudy grains contain abundant dust particles. Needle-like grains are very fine, cloudy, and are pink in colour. Zircons from sample 2 are transparent shapless isometric grains and particles; those from sample 3 are cloudy particles of pink to light brown colour. Grains from sample 4 are pink, cloudy, and stubby in shape; some are rimmed by a thin transparent mantle. The cloudy appearence of these grains is likely to reflect their highly micro-cracked condition and the abundance of dust particles. Except for sample 2, all prismatic grains show the same morphologies suggesting the existence of a co-genetic complex. Optical characters of grains from samples 1 and 3 show that they grew during a single event and were not significantly recrystallized.

Table II. U-Pb zircon isotopic data.

Sample no.	grain population	weight	[U] ppm	[Pb] ppm	$^{206}Pb/^{204}Pb$	$^{207}Pb/^{206}Pb$	$^{208}Pb/^{206}Pb$	$^{206}Pb/^{238}U$	$^{207}Pb/^{235}U$	$^{207}Pb/^{206}Pb$
1 a	transparent	0.89	356	81.4	19370	0.8272±5	0.25558	0.19348	2.2068	1263±1.1
b	cloudy	1.08	637	134	2008	0.08109±4	0.31394	0.17095	1.9114	1224±1.1
2	transparent	0.22	347	150	319	0.17016±8	0.08989	0.34268	8.0395	2559±0.8
3 a	transparent	0.43	519	166	161	0.08442±9	0.20335	0.21114	2.4575	1302±2.1
b	cloudy	0.69	464	144	159	0.08445±8	0.19117	0.20484	2.3853	1303±2.0
4	cloudy	0.03	467	186	66.7	0.08478±39	0.21920	0.17633	2.0612	1310±9.0

Note: Decay constants used for isotopic ratios calculations recommended by Steiger & Jager (1977).

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Six zircon fractions were analysed for U-Pb isotopic ratios. The data obtained are listed in Table II. Two populations (transparent and cloudy) from sample 1 (sequence 3 and subvolcanic rocks) define a pseudo-isochron line (Fig. 2) intersecting concordia at 1302 ± 4.0 Ma and 364 ± 16 Ma. Two populations (transparent and cloudy) from sample 3 and from sample 4 (sequence 1) show intersections at 1300 ± 3.5 and -63 ± 68 Ma (MSWD 0.126). Both transparent grain fractions exhibit less Pb loss compared to their cloudy counterparts, which may be explained by easier Pb loss from disturbed (cloudy) grains during later thermal events.

Zircons from sample 2 show quite different isotopic ratios from the other samples. Because the rock studied is probably tuffaceous in origin, clastic material is likely to have been added, and zircon grains may represent refractory phases from deep crustal or mantle sources, or xenoclasts of fragmented country rocks. As zircons from sample 2 have a $^{207}Pb/^{206}Pb$ model age of 2559 Ma, these rocks may have Archaean crustal precursors involved into their petrogenesis.

Conclusion

All zircon populations measured are likely to have been crystallized during the same thermal event at 1300±4 ma. At present we can not determine unequivocally whether this event was igneous or metamorphic in origin although an igneous origin of zircon growth seems to be more plausible. However, the presence of highly elongated needle-like grains suggests that the volcanic rocks have undergone at least two zircon growth events. Indistinguishable zircon ages for sequence 1 and sequence 3 probably reflect relatively short time lapse (within analytical errors) separating two different igneous events. The age obtained coincides well with the age of Vestfold Hills dolerite dyke emplacement event at 1250 Ma (Black *et al.* 1991) implying igneous activities to be roughly co-eval in regions of different tectonic environments. Crustal extension in Vestfold Hills seems to overlap in time with crust-forming event in Wegener-Mawson Mobile Belt.

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