From Archaean to Proterozoic on Hardangervidda, South Norway

ANNE BIRKELAND[1], ELLEN M. O. SIGMOND[1], MARTIN J. WHITEHOUSE[2] & JESSICA VESTIN[2]

[1] *Geological Survey of Norway, P.O. Box 3006-Lade, N-7002 Trondheim, Norway.*
[2] *Laboratory of Isotope Geology, Swedish Museum of Natural History, Box 50007, S-104 05 Stockholm, Sweden.*

Crust formation in South Norway - ambiguities of time and process

Precambrian crust in southern Norway (Fig. 1) is part of the Southwest Scandinavian Domain which forms the southwestern rim of the Fennoscandian Shield (Gorbatschev & Bogdanova 1993), interpreted to be younger than 1800 Ma. The present model for the evolution of the Fennoscandian Shield involves amalgamation of Archaean microcontinents and crustal growth by westward accretion during the Paleoproterozoic (Gower et al. 1990). Ragnhildstveit et al. (1994) reported U-Pb isotope ages of 2503 Ma on single zircons from the Hardangervidda. This indicated that the crust of southern Norway could have a longer history than previously believed. The present paper is part of a project initiated to gain a better understanding of when and how the crust of South Norway formed.

The use of high-resolution SIMS combined with BSE and CL unravels zircon ages

Using a secondary ion mass spectrometer (SIMS) capable of high sensitivity, high mass-resolution, U-Pb analysis of very small areas of zircon crystals (typically <30 μm diameter spots) can yield high spatial resolution geochronology. This is a powerful technique for zoned zircons from polyphase terranes such as those in southern Norway. Imaging of the crystals with back-scattered electrons (BSE) or cathodoluminiscence (CL) in a scanning electron microscope (SEM) enables one to interpret whether the zircon has grown by magmatic or metamorphic processes, as well as revealing whether the crystal has been abraded by sedimentary processes.

For the present study the same granite of Ragnhildstveit et al. (1994) was resampled for SIMS analyses of zircons. The analysed sample, a severely deformed and metamorphosed, fine-grained pink granite, belongs to a multiplicity of granites of different ages and sizes which, in this area, intrude metasedimentary and possibly also volcanic rocks.

Zircons were separated from a rock sample of *c.* 20 kg, mounted in epoxy, and polished to expose sections through the crystals. BSE, CL imaging and SIMS analyses were performed on the same crystals. BSE and CL utilised the SEM at IKU Petroleum Research in Trondheim, Norway. SIMS analyses were performed using the Cameca IMS1270 instrument of the joint-Nordic facility for geological SIMS (NORDSIM), located at the Swedish Museum of Natural History, Stockholm, Sweden. U-Pb analytical procedures closely follow those described by Whitehouse et al. (1997) with enhancement of secondary Pb ion yield by leaking oxygen into the sample chamber. Tables of analytical data are available from the authors on request.

Archaean to Proterozoic on Hardangervidda

Two major groups of concordant (within 2 σ-error) ages were obtained (Fig. 2) at c. 1600 Ma (36 analyses) and c. 1500 Ma (15 analyses), with other concordant ages at c. 1100 Ma (2 analyses), 2838 Ma (1 analysis) and 2735 Ma (1 analysis). 1229 Ma (1

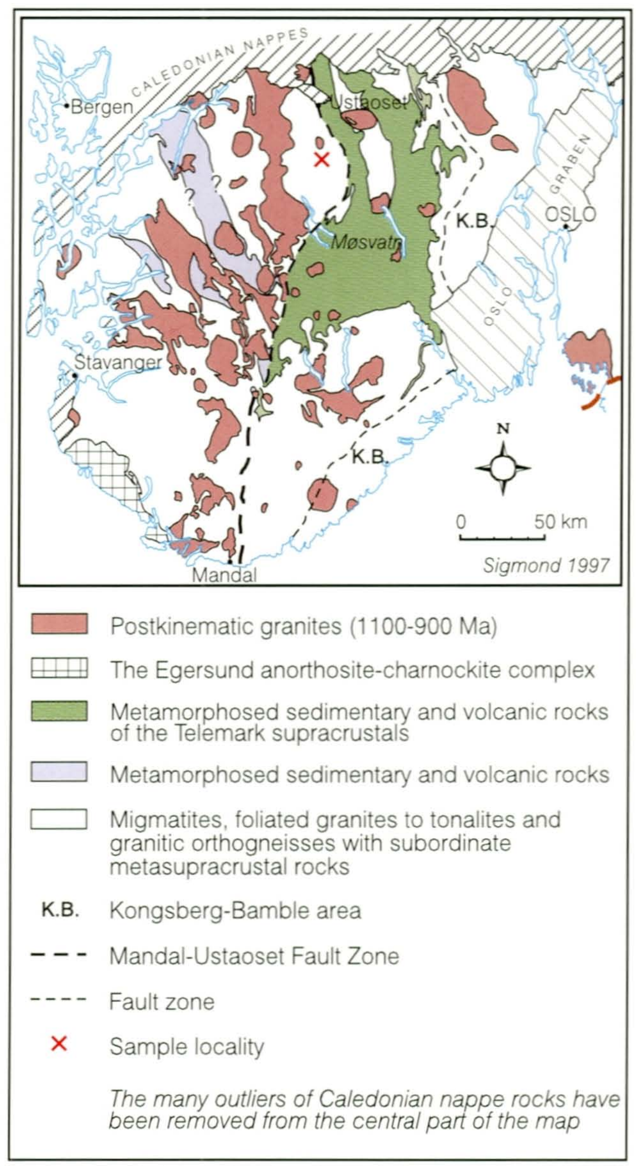

Fig. 1. Geological map showing the main lithotectonic units in the Precambrian of Southwest Norway.

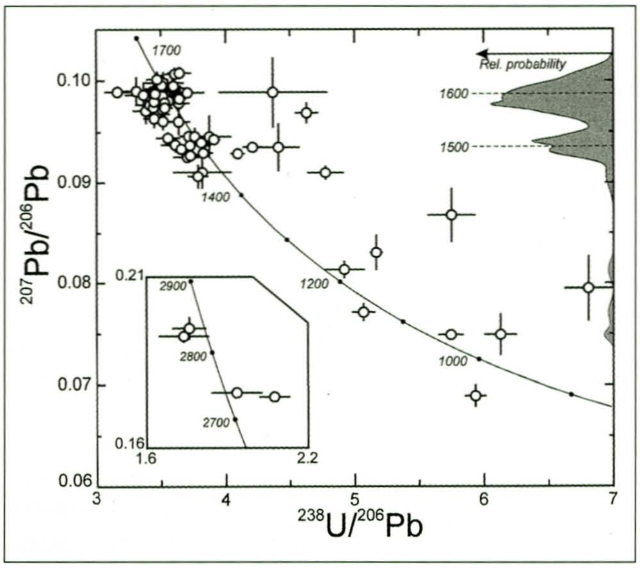

Fig. 2. Tera-Wasserburg concordia diagram of SIMS zircon analyses with 1s error bars (inset shows Archaean part of curve). The relative probability curve for concordant analyses is shown to the right.

analysis) is also a concordant age; however, in this case the ion beam has touched the older core of the crystal, so the age is probably a mixing between the core-age (1601 Ma) and a Sveconorwegian age of c. 1100 Ma.

The 1600 Ma and 1500 Ma ages record two distinct events, as evident from the concordia diagram and the probability curve (Fig. 2). Zircons yielding these ages are igneous with pyramidal prismatic habit and exhibit well-evolved oscillatory zoning (Figs. 3a and 3b). 1600 Ma-old zircons are not observed to be overgrown by 1500 Ma-zircon, i.e. there are two discrete populations. 1600 Ma is interpreted as the age of the intrusion, whereas the 1500 Ma age records injection of new magma into the already existing granite.

The present analyses record one post-igneous event (Figs. 2, 3a and 3b). The age is not well enough represented in the data set to make precise age interpretation; it is clear, however, that it is Sveconorwegian. The CL and BSE images (Figs. 3a and 3b) show that it is a distinct overgrowth on igneous crystals of both the 1600 Ma and the 1500 Ma zircon-populations, and that the event is probably metamorphic on the basis of the rather diffuse zonation.

The granite has inherited zircons recording two statistically distinct Archaean events (Fig. 2 inset). The oscillatory zoning apparent from the CL images (Fig. 3c) shows that both events were igneous. Furthermore, neither the core nor the outer part of the crystal is rounded, showing that the crystal has not been abraded, arguing against lengthy sedimentary transport. More likely, both the core and the outer crystal grew in a magmatic environment close to the present location of the rock.

Conclusions

The main igneous event at c. 1600 Ma was succeeded by input of new magma at c. 1500 Ma, and subsequent metamorphism at c. 1100 Ma. Furthermore, the rock contains a record of two Archaean magmatic events, close in age but statistically distinct. The absence of abrasion of the Archaean zircons justifies the hypothesis that Archaean magmatism took place in the same region where the zircons are now found. It is thus likely that Archaean magmatic crust formation processes are represented in South Norway.

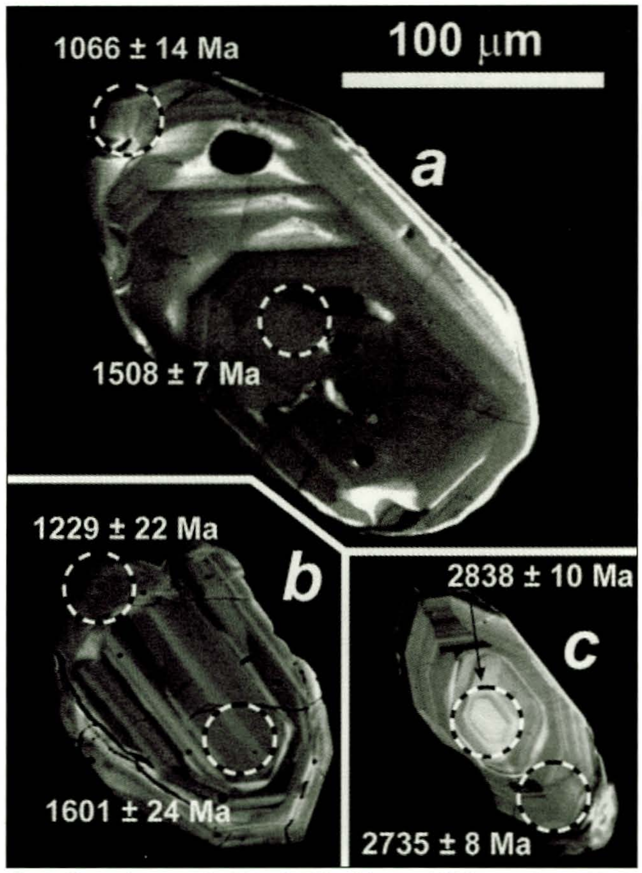

Fig. 3. Zircon images: a) 1508 +/- 7 Ma old crystal (CL), note the 1066 +/- 14 Ma old rim ; b) 1601 +/- 24 Ma old crystal (BSE). The age 1229 Ma of the rim is probably a mix between the 1601 Ma old core and c. 1100 Ma; c) Archaean zircon (CL).

Acknowledgements

We are grateful to Gunborg Bye Fjell, Tony Boasson and Torbjørn Sunde for technical assistance. The manuscript has benifitted from comments by Stefan Claesson and critical rewiews by Suzanne McEnroe, Peter Robinson and Tom Andersen.

References

Gorbatschev, R. & Bogdanova, S. 1993: Frontiers in the Baltic Shield. *Precambrian Research 64*. 3-21.

Gower, C. F., Rivers, T. & Ryan, A. B. 1990: Mid-Proterozoic Laurentia-Baltica (NENA): An overview of its geological evolution and a summary of the contributions made by this volume. *In*: Gower, C. F., Rivers, T. & Ryan, A. B. (eds.) *Mid-Proterozoic Laurentia and Baltica*. Geological Association of Canada Special Paper 38, 1-20.

Ragnhildstveit, J., Sigmond, E. M. O. & Tucker, R. D. 1994: Early Proterozoic supracrustal rocks west of the Mandal-Ustaoset fault zone, Hardangervidda, South Norway. *(Abstract), Terra Abstracts, abstract supplement No. 2 to Terra Nova 6*, p 15.

Whitehouse, M. J., Claesson, S., Sunde, T. & Vestin, J. 1997: Ion-microprobe U–Pb zircon geochronology and correlation of Archaean gneisses from the Lewisian Complex of Gruinard Bay, north-west Scotland. *Geochimica et Cosmochimica Acta* 61, 4429-4438.