TIMESCALES OF CONTINENTAL SUBDUCTION: CONSTRAINTS FROM THE ULSTEINVIK METAPELITE IN THE WESTERN GNEISS REGION, NORWAY

March, S[1], Hand, M[1], Tamblyn, R[1], Carvalho, B[2] & Clark, C[3]

[1]DEPARTMENT OF EARTH SCIENCES, UNIVERSITY OF ADELAIDE, SOUTH AUSTRALIA
[2]DIPARTMENTO DI GEOSCIENZE, UNIVERSITA DEGLI STUDI DI PADOVA, ITALY
[3]SCHOOL OF EARTH AND PLANETARY SCIENCES, CURTIN UNIVERSITY, AUSTRALIA

THE UNIVERSITY of ADELAIDE
AusIMM THE MINERALS INSTITUTE
Playford Trust
Providing Prestigious Scholarships for High-Achieving South Australians

Introduction

The **Western Gneiss Region** (WGR), Norway is an archetypal continental **ultrahigh-pressure** (UHP) terrane with an extensive metamorphic history, recording the **subduction** and subsequent exhumation of **continental crust** to depths exceeding **120 km**. The WGR (Fig. 1) is one of the largest, best-exposed, and most-studied ultrahigh-pressure terranes on Earth. **Metapelitic rocks** have been largely ignored in past efforts to understand the tectono-metamorphic history of the WGR during continental subduction and have been explored in this study. A combined approach utilising U–Pb multi-mineral **geochronology** coupled with **mineral equilibria forward modelling** is applied to further **illuminate the P–T evolutionary history** of the WGR. The results from this research suggest that vUlsteinvik was a constituent of the allochthonous Blåhø nappe and that the terrane experienced a long-lived prograde history prior to its deep burial.

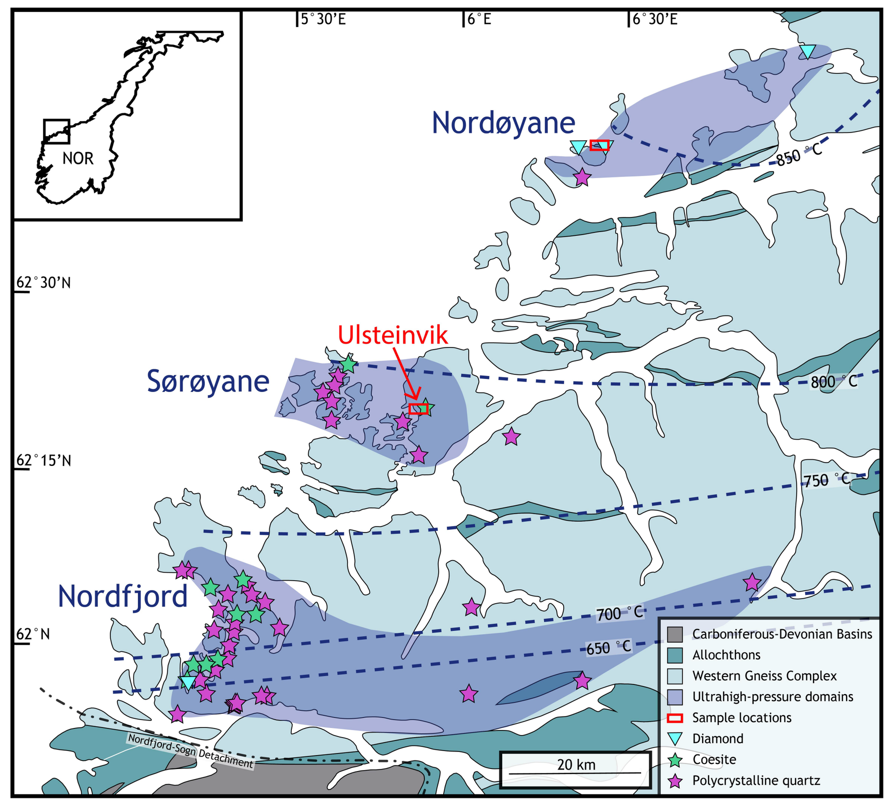

Figure 1: Geologic map of the Western Gneiss Region, Norway, highlighting UHP terranes and sample locations. Coesite locations from Wain et al. (1997), Cuthbert et al. (2000), Carswell et al. (2003), Root et al. (2005) and Spengler (2006). Diamond locations from Dobrzhinetskaya et al. (1995), van Roermund et al. (2002), Vrijmoed et al. (2008) and Smith and Godard (2013).

Geological Background

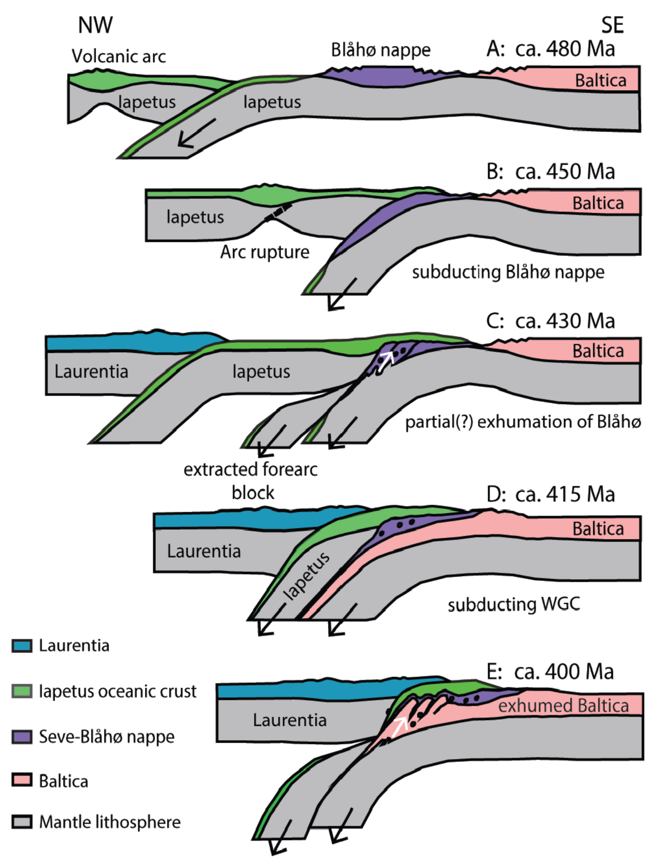

Figure 2: Hypothesised tectonic evolution of the Western Gneiss Region, Norway during the Caledonian. Modified from Majka et al. (2014).

~480–430 Ma: Early subduction and imbrication of allochthonous nappes, including the Blåhø nappe.

~430 Ma: The Iapetus Ocean closes and Baltica (along with overlying allochthons) subducts beneath Laurentia.

~430–415 Ma: The Western Gneiss Region subducts to depths exceeding 120 km and experiences peak metamorphic conditions of ~795 °C and 3.2 GPa.

~400 Ma: Exhumation of the WGR.

Results

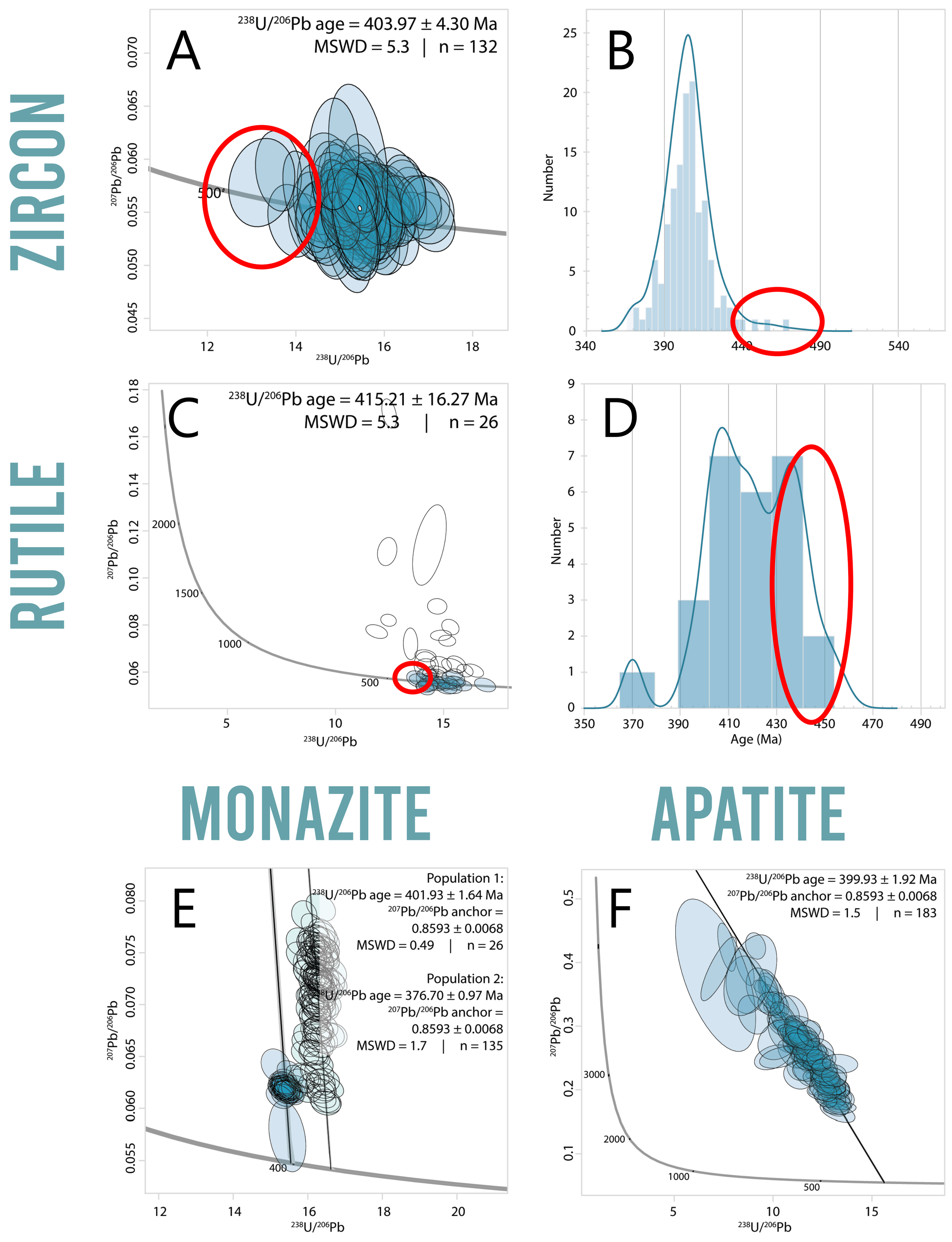

Figure 3: Ulsteinvik geochronology results. Pre-Scandian ages are circled in red. A) Zircon Tera Wasserburg concordia plot. B) Zircon cumulative probability distribution plot. C) Rutile Tera Wasserburg concordia plot. D) Rutile cumulative probability distribution plot. E) Monazite Tera Wasserburg concordia plot anchored by a calculated $^{207}Pb/^{206}Pb$ ratio from biotite, F) Apatite Tera Wasserburg concordia plot anchored by biotite $^{207}Pb/^{206}Pb$.

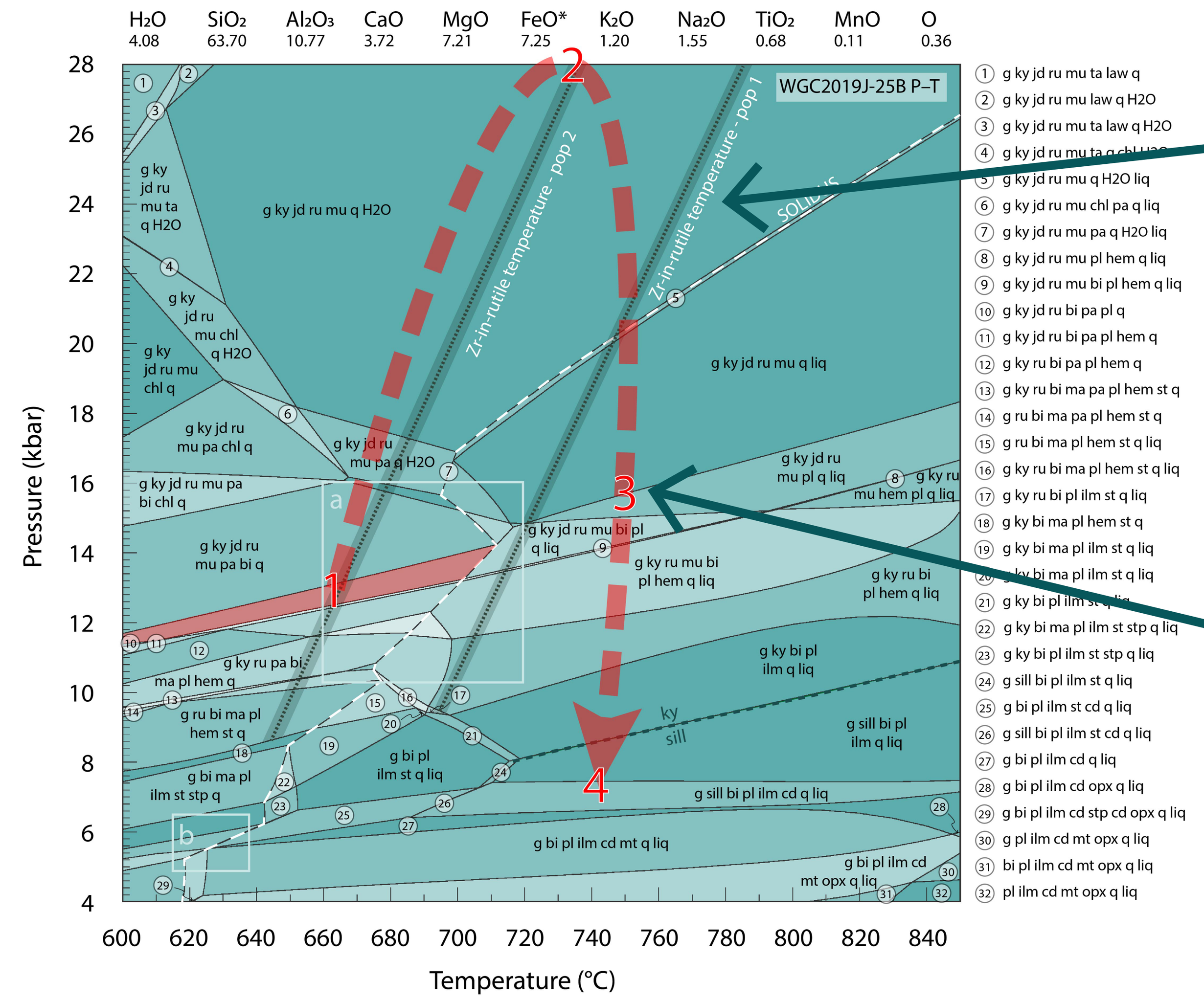

Figure 4: P–T pseudosection for the Ulsteinvik metapelite. The red arrow represents the inferred P–T path, defined by points 1-4. The red shaded area represents the prograde field (Point 1). Point 2 is a minimum peak constraint. Point 4 defines a P–T point calculated from a retrograde bulk composition. Variance increases with shading in the diagram. Bulk composition used for the calculation of he phase diagram is listed in mol% at the top of the diagram. Oxidation (Mo) was constrained at 0.15. Abbreviations: g = garnet, ky = kyanite, sill = sillimanite, jd = jadeite, ru = rutile, mu = muscovite, ta = talc, law = lawsonite, pa = paragonite, ma = margarite, bi = biotite, chl = chlorite, pl = plagioclase, hem = hematite, ilm = ilmenite, st = staurolite, stp = stipnomelane, q = quartz, mt = magnetite, opx = orthopyroxene, cd = cordierite, liq = liquid, H2O = water.

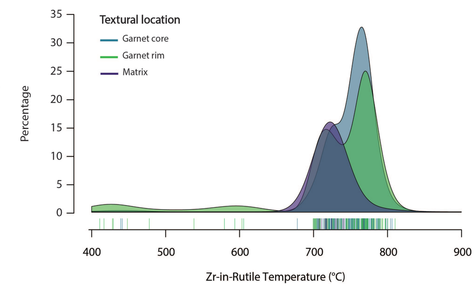

Figure 5: Zr-in-rutile temperature distribution coloured by textural location. Population 1 represents the tallest distribution peak.

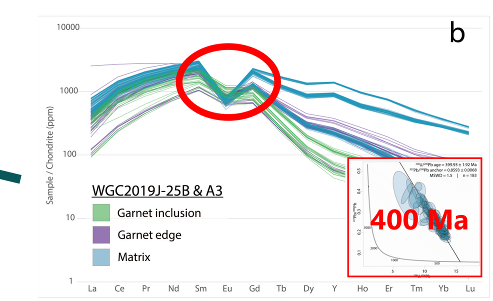

Figure 6: Apatite rare earth element (REE) spiderplot, highlighting the negative Eu anomaly in matrix grains. Inset figure depicts the apatite concordia plot, calcuating an age of ~400 Ma.

Zircon, rutile, monazite and apatite **U–Pb geochronology** conducted on the Ulsteinvik metapelite documents a **predominantly Scandian** (430–380 Ma) history, correlated with the main subduction episode in the WGR (Fig. 2C). Additionally, zircon and rutile recorded a small percentage of ages ranging from 480–430 Ma that **pre-date Baltican subduction** (Fig. 3A-D).

Mineral equilibria forward modelling for the Ulsteinvik sample yielded a complex diagram (Fig. 4). The presence of rutile, muscovite and plagioclase **inclusions** inside garnet constrained the prograde assemblage (Fig. 4; Point 1). Minimum peak conditions are interpreted to occur at **~2.9 GPa** and **760 °C** along the intersect of the coesite-in line (Fig. 4; Point 2) with population two Zr-in-rutile. This is based on the observation of **coesite** in the neighbouring Hareidland eclogite (Carswell et al. 2003). The presence of a negative Eu anomaly in ~400 Ma matrix apatite (Fig. 6) suggests the rock did not traverse through plagioclase-stable fields and **remained above 16 kbar** (Fig. 4; Point 3) **until after 400 Ma**. Calculation of a single P–T point constrains retrograde conditions at ~7 kbar and ~740 °C.

Conclusions

1. Zircon and rutile record some U–Pb ages that **pre-date** the main Scandian UHP subduction episode in the WGR. These ages correlate with the early subduction of allochthonous terranes (Fig. 2A, B) and support the conclusion made by Root et al. (2005) regarding Ulsteinvik's affinity for the **Seve-Blåhø** nappe.

2. Ulsteinvik experienced a **long-lived prograde history** and was at pressures that inhibited plagioclase growth until as late as 400 Ma (Fig. 4, 6).

3. Despite being volumetrically minor, **metapelitic rocks** in the WGR contain an **untapped reservoir** of information. A campaign-style study of WGR metapelites is highly encouraged in a future study.

References

- Carswell, D. A., Tucker, R. D., O'Brien, P. J., & Krogh, T. E. (2003). Coesite micro-inclusions and the U/Pb age of zircons from the Hareidland Eclogite in the Western Gneiss Region of Norway. Lithos, 67(3-4), 181-190. doi:10.1016/S0024-4937(03)00014-8
- Cuthbert, S. J., Carswell, D. A., Krogh-Ravna, E. J., & Wain, A. (2000). Eclogites and eclogites in the Western Gneiss Region, Norwegian Caledonides. Lithos, 52(1-4), 165-195. doi:10.1016/S0024-4937(99)00090-0
- Dobrzhinetskaya, L. F., Eide, E. A., Larsen, R. B., Sturt, B. A., Trønnes, R. G., Smith, D. C., Taylor, W. R., & Posukhova, T. V. (1995). Microdiamond in high-grade metamorphic rocks of the Western Gneiss region, Norway. Geology, 23(7), 597-600.
- Majka, J., Rosén, Å., Janák, M., Froitzheim, N., Klonowska, I., Manecki, M., Sasinková, V. & Yoshidam K. (2014). Microdiamond discovered in Seve Nappe (Scandinavian Caledonides) and its exhumation by the "vacuum-cleaner" mechanism. Geology, 42(12), 1107-1110.
- Root, D. B., Hacker, B. R., Gans, P. B., Ducea, M. N., Eide, E. A., & Mosenfelder, J. L. (2005). Discrete ultrahigh-pressure domains in the Western Gneiss Region, Norway: implications for formation and exhumation. Journal of Metamorphic Geology, 23, 45-61. doi:10.1111/j.1525-1314.2005.00561.x
- Sizova, E., Hauzenberger, C., Fritz, H., Faryad, S.W., & Gerya, T. (2019). Late orogenic heating of (ultra)high pressure rocks: slab rollback vs. slab breakoff. Geosciences, 9(12), 499.
- Smith, D. C., & Godard, G. (2013). A Raman spectroscopic study of diamond and disordered sp3-carbon in the coesite-bearing Straumen Eclogite Pod, Norway. Journal of Metamorphic Geology, 31(1), 19-33.
- Spengler, D., van Roermund, H. L. M., Drury, M. R., Ottolini, L., Mason, R. D., & Davies, G. R. (2006). Deep origin and hot melting of an Archaean orogenic peridotite massif in Norway. Nature, 440(13), 913-917.
- van Roermund, H. L. M., Carswell, D. A., Drury, M. R., & Heijboer, T. C. (2002). Microdiamonds in a megacrystic garnet websterite pod from Bardane on the island of Fjørtoft, western Norway: Evidence for diamond formation in mantle rocks during deep continental subduction. Geology, 30(11), 959-962.
- Vrijmoed, J. C., Smith, D. C., & van Roermund, H. L. M. (2008). Raman confirmation of microdiamond in the Svartberget Fe-Ti type garnet peridotite, Western Gneiss Region, Western Norway. Terra Nova, 20(4), 295-301.
- Wain, A. (1997). New evidence for coesite in eclogite and gneisses: defining an ultrahigh-pressure province in the Western Gneiss Region of Norway. Geology, 25, 927-930.