GEOLINES 23

# **Stop 3-2 (Day 3).** Eclogite, Louka (Roadcut with Meter-Scale Boudin of Eclogite, surrounded by Layered Garnet Amphibolite – Retrograded Eclogite)

Coordinates: N50°02'30.0" E12°48'53.8" (33U 343545 5545550)



**Fig. 12.** Photomicrograph of Sítiny serpentinite, Locality 1 (plane polarized light). Abbreviations: c, chlorite after spinel; o, serpentine after olivine; t, serpentine after tremolite.

The Louka eclogite is a foliated, medium-grained kyanite-quartz eclogite, which is about 50% retrograded to symplectite and ke-lyphite (Fig. 13). The eclogite facies assemblage consists of garnet, omphacite, quartz, kyanite, and 2–3% medium-grained, early amphibole, with accessory rutile, ilmenite, and apatite. Garnet has an intermediate composition (Fig. 4) and exhibits a slight, prograde compositional zoning, in which Grs and Sps decrease from core to rim, and Alm and Prp increase, with a slight reversal in trend at the grain margin (Fig. 10). The jadeite content in omphacite ranges from 40 to 50% (Fig. 5), and early amphibole is magnesiotaramite, with 6.27 Si atoms p.f.u. and Mg# of 73.

The kyanite-quartz eclogite at this locality yields a pressure of 21.7 kbar and a temperature of 670 °C (Fig. 11), following the method of Ravna and Terry (2004). The surrounding amphibolite yields a range of P-T conditions, from 8 to 12 kbar and from 620 to 750 °C, depending on the combination of thermobarometric methods used (Timmermann et al., 2004).

The Louka locality has provided numerous geochronological data which constrain the timing of protolith genesis and metamorphism in the MLC (Table 1). The kyanite-quartz ecogite has yielded a Sm-Nd garnet-omphacite age of  $377 \pm 7$  Ma (Beard et al., 1995) and a concordant U-Pb age for zircon of  $382 \pm 3$  Ma (Timmermann et al., 2004). The surrounding amphibolite gives a concordant U-Pb age for zircon of  $540 \pm 9$  Ma, a U-Pb lower intercept age for zircon of  $373 \pm 10$  Ma, and a concordant U-Pb age for titanite of  $365 \pm 7$  Ma. Other amphibolites in the vicinity of Louka give K-Ar ages for hornblende of  $379 \pm 9$ ,  $374 \pm 7$ , and  $368 \pm 8$  Ma (Kreuzer et al., 1992). As discussed previously, we interpret these data to reflect the genesis of oceanic crust in Early Cambrian time, followed by metamorphism during Frasnian to Famennian subduction and exhumation.



Fig. 13. Photomicrograph of Louka kyanite-quartz eclogite, Locality 2 (plane polarized light). Abbreviations: k, kyanite; g, garnet; o, omphacite; q, quartz. Garnet is surrounded by amphibole kelyphite, omphacite is extensively replaced by symplectite, and kyanite is surrounded by an extremely finegrained reaction rim of spinel and plagioclase, which contains lamellar sapphirine and corundum.

## **Stop 3-3 (Day 3).** Amphibolite and Feldspar Veins, Tisová (Roadcut in Amphibolite)

Coordinates: N50°02'43.3" E12°49'34.4" (33U 344365 5545937)

Massive to layered amphibolite, both garnet-bearing and garnetfree types, are exposed in this roadcut. Locally, amphibolite contains symplectitic intergrowths of sodic augite, amphibole, and plagioclase (Fig. 14), presumably after omphacite, demonstrating that amphibolite is the retrograde product of eclogite. More commonly, garnet amphibolite is extensively recrystallized to a granoblastic, foliated assemblage of mediumgrained garnet and fine-grained amphibole, plagioclase, quartz, titanite, and ilmenite (Fig. 15). Rutile occurs as inclusions in garnet.

#### 79



 Fig. 14. Photomicrograph of Tisová amphibolite, Locality 3 (plane polarized light), illustrating clinopyroxene-amphiboleplagioclase symplectite after omphacite.



• Fig. 15. Photomicrograph of Tisová amphibolite, Locality 3 (plane polarized light). The amphibolite assemblage is garnet, hornblende, calcic plagioclase, quartz, titanite, and ilmenite.



• Fig. 16. Outcrop at the Tisová roadcut, Locality 3, where deformed feldspar veins intrude amphibolite.

A prominent feature of this outcrop is the presence of feldspar-rich veins, 1 to 10 cm in thickness, which have been variously described as pegmatite veins (Bowes et al., 2002), felsic leucosomes (Timmermann et al., 2004), and feldspar veins (Zulauf, 1997). These veins are significant because they cross-cut foliation in amphibolite, but are themselves folded (Fig. 16), having been described as constrictional mullions by Zulauf (1997, see his Fig. 3C). Thus, these veins place important constraints on the timing of metamorphism and exhumation in the MLC. Hornblende from amphibolite at this locality yields a  ${}^{40}$ Ar/ ${}^{39}$ Ar age of 377 ±4 Ma (Singer, in preparation). In the feldspar veins, two fractions of titanite yield almost concordant U-Pb ages of 366 ±13 and 378 ±4 Ma (Timmermann et al., 2004), and hornblende and biotite yield  ${}^{40}$ Ar/ ${}^{39}$ Ar ages of 379 ±4 (Bowes *et al.*, 2002) and 374 ±1 Ma (Singer, in preparation), respectively. All of these results, including that for biotite, are within error of each other and indicate that rapid cooling of the MLC through ~500–350 °C was complete by Famennian time.

### **Stop 3-4 (Day 3).** Eclogite, Tisova (Small, Abandoned Quarry in Eclogite) Coordinates: N50°02'12.8" E12°50'49.5"

Fine- to medium-grained quartz eclogite is exposed in this quarry, and boulders of kyanite-quartz eclogite occur in a field *c*. 50 m. away. As described by O'Brien (1992, 1997), eclogite at this locality has been weakly overprinted by a granulite facies stage of recrystallization, followed by a more pervasive amphibolite facies stage. As a result, omphacite in kyanite-quartz eclogite has been completely replaced by symplectite, although a few relict grains of omphacite persist in quartz eclogite (Fig. 17); the jadeite content of such relict omphacite ranges from 27 to 38% (Fig. 5). Garnet in quartz kyanite is richer in Alm + Sps component than that in kyanite-quartz eclogite (Fig. 4), and garnet in kyanite-quartz eclogite shows strong prograde compositional zoning, with a core to rim decrease in Alm, Grs, and Sps, and increase in Prp (Fig. 10; *cf*. Fig. 3 in O'Brien, 1997). The cores of such strongly zoned garnet grains contain inclusions of pargasitic amphibole, clinozoisite, and plagioclase.

Because omphacite in kyanite-quartz eclogite has been completely replaced by symplectite in samples examined by us, no P-T estimates for the eclogite stage of this rock type were possib-

Fig. 17. Photomicrograph of Tisová quartz eclogite, Locality 4 (plane polarized light). Abbreviations: g, garnet; o, omphacite; r, rutile. Omphacite has been largely replaced by symplectite. Note abundant quartz inclusions in garnet. le. However, the presence of relict omphacite in quartz eclogite allows a minimum P-T estimate to be made, which is 13.7 kbar, 670 °C. Note that O'Brien (1997) reports values of 17.0–19.5 kbar and 640–715 °C for eclogite from the Tisová locality (Fig. 11).



### Stop 3-5 (Day 3). Metagabbro, Výškovice (Abandoned Quarry in Metagabbro)

Metagabbro at this locality has retained a medium- to grained, ophitic texture (Fig. 18) and a relict igneous

assemblage of augite ( $X_{Mg} = 0.85$ ), enstatite ( $X_{Mg} = 0.70$ ), pargasitic to edenitic amphibole, minor biotite, plagioclase, and accessory apatite, rutile, and ilmenite. Amphibole is interstitial to, and surrounds augite and enstatite. Locally, augite and amphibole are poikilitic. Biotite is associated with, and enclosed by, amphibole.

Partial recrystallization has resulted in the growth of finegrained garnet coronas at contacts between ferromagnesian minerals and plagioclase (Fig. 19), replacement of calcic igneous plagioclase by very fine-grained sodic plagioclase (An<sub>33</sub>) and zoisite, growth of very fine-grained sodic augite at the margins of igneous augite, and replacement of brown, igneous amphibole by green, metamorphic amphibole. Garnet has a composition of  $Alm_{38.44}Prp_{30.40}Grs_{22.26}Sps_{0.1}$ , shows a slight prograde zonation with a core to rim increase in  $X_{Mg}$ , and locally contains tiny kyanite inclusions. Metamorphic sodic augite contains up to 17 mol% jadeite, and metamorphic amphibole contains less TiO<sub>2</sub> than does its igneous counterpart, 0.2–0.3 wt % vs. 2.1–2.4 wt%.

P-T conditions for the recrystallized assemblage, garnet + plagioclase + sodic augite + kyanite + quartz, were estimated to be 12.0–13.0 kbar and 585–615 °C (Fig. 11), as determined by exchange thermobarometry and Thermocalc. Bowes and