interplay of tectonics and heat flow (Spear et al. 1984). Metamorphism is constrained to tectonically active belts with increased heat flow, i.e. areas of active plate margins. It is often related to thickening and thinning of the continental crust, and processes such as burial and uplift of the rocks. The shape and sense of the P-T paths are good indicators of processes that contribute to the formation of the rocks.

Recent reviews of P-T metamorphic conditions and P-T-t paths of granulites worldwide show their large variability, reflecting numerous processes leading to their formation (Harley 1989). It is now obvious that P-T conditions of granulite metamorphism are not restricted to the P-T box advocated by Bohlen (1987).

There are basically two types of P-T paths following the peak metamorphism observed in granulites - isobaric cooling (IBC) and isothermal decompression (ITD). These trajectories can be preceded by variable processes, corresponding both to collisional and extensional environment. These processes are indicated by prograde P-T paths, that together with the retrograde one defines a sense of the path. It has been shown that this sense can be 'clockwise' (T_{max} before P_{max}) or 'anticlockwise'. The first type can be generated by many mechanisms (cf. Harley 1989), the second is commonly related to magmatic accretion (cf. Bohlen 1987).

Peak of metamorphism is generally registered by the mineral assemblage in the rocks, as well as their retrograde reequilibration. Prograde portion of the P-T paths in granulites, however, is commonly obliterated due to high temperatures of granulite metamorphism (high diffusion rates). Then, tectonic processes have to be inferred based only on the post-peak segments of the P-T path. For such inferences, knowledge of structural relationships, timing of events, and geochemical data are necessary (see also Harley 1989).

This work makes use of the principles given above to constrain the tectonometamorphic evolution of the north Bohemian granulites.

3. General geology

All the granulite occurrences of the north Bohemia that were studied are situated in the vicinity of the Litoměřice Deep Fault, in the northern part of the Bohemian Massif. This fault represents an eastern part of a NE-SW trending fault zone, and it is considered a boundary between Saxothuringicum (NW) and Bohemicum (SE; Chaloupský 1989) (Fig. 3.1). Its significance as a deep-seated tectonic boundary is also supported by associated ultrabasic volcanic rocks (polzenites), by the presence of an important mylonite zone (Kopecký et al. 1961), and by the different character of the crystalline basement on both sides of the fault. The presence of high-grade rocks (gneisses, granulites) in the crystalline basement of the studied territory (NW block, Saxothuringicum) contrasts with that of the SE block (Bohemicum), with only low- to medium-grade metamorphism (Svoboda et al. 1966).

For the zone mentioned above, Kopecký (1971a in Kopecký 1987, 1988) introduced the term 'Ohře rift' (discussed in Kopecký 1986). The term 'granulite complex' has been used for highly metamorphosed rocks of the north Bohemian crystalline basement

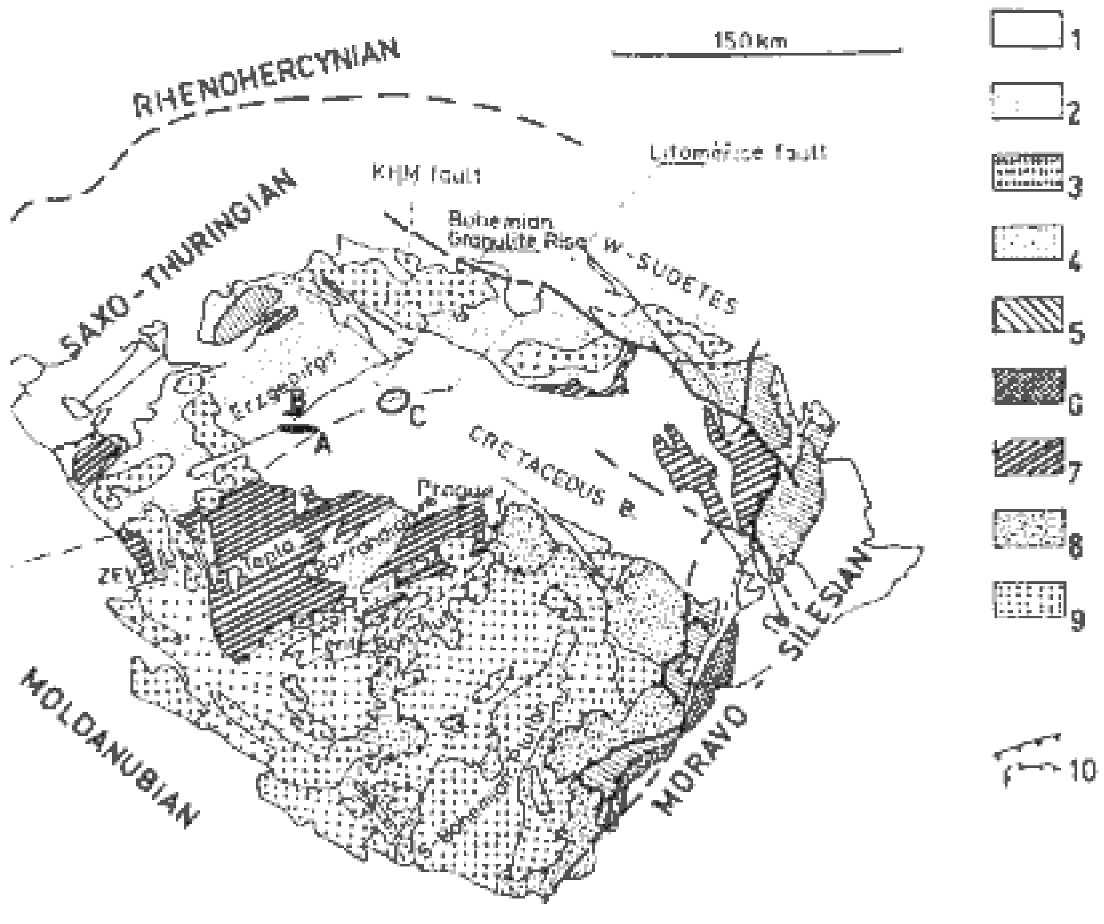

Fig. 3.1 Simplified geological map of the Bohemian Massif (according to Franke 1989), showing the position of studied areas (A - Ohře crystalline area, B - zone Blahuňov - Málkov, C - České středohoří crystalline basement). 1 - Devonian and Carboniferous sedimentary and volcanic rocks, unmetamorphosed, 2 - Pre-Devonian (including Precambrian), partly with Variscan metamorphism, 3 - Paleozoic rocks undifferetiated, partly metamorphosed, 4 - Variscan metamorphic rocks, 5 - Cadomian basement of the Moravo-Silesian, 6 - Cadomian basement (partly with Variscan reactivation) of the Teplá/Barrandian microplate, 7 - Gföhl unit of the Moldanubian region; Sowie Góry block; 8 - Drosendorf unit of the Moldanubian region, 9 - Variscan granites (largely post-tectonic), 10 - main thrusts (partly sutures).

(e.g.Zoubek & Škvor 1963).

Granulites and granulitic gneisses have been described in three separate areas (Fig. 3.1):

A. The Ohře crystalline area (cf. Zartner 1929; Append. I). Granulites and granulitic gneisses are exposed in the erosive window in young platform sediments and abundant Tertiary volcanic rocks along the Ohře river. They are associated with two-mica orthogneisses, strongly migmatized two-mica gneisses and migmatites. Granulites occur in morphologically distinct, but separate rock outcrops.

B. The zone Blahuňov - Málkov (cf. Holubec 1956; Fig. 3.2). Exposures of granulitic gneisses on the E slope of the Krušné hory Mts. Muscovite - garnet paragneisses and biotite to two-mica paragneisses represent the host rocks of granulitic gneisses. The granulite body is elongated in east-west direction, parallel to the foliation of the surrounding metasediments. Further south, an E-W elongated serpentinite body occurs (Sattran 1966).

C. České středohoří. Granulites are found in boreholes (cf. Kopecký & Sattran 1966) and as xenoliths in Tertiary volcanic rocks (cf. Ebert 1932). They are associated with garnet peridotites, garnet pyroxenites and amphibolite-facies gneisses (Shrbený & Ulrych 1988), and charnockites (Opletal & Vrána 1989). Two of the boreholes - T7 and RPZ31 - and some T38 borehole samples, were studied in detail. All the xenoliths investigated are acid kyanite-bearing granulites (localities Sviňky, Újezd u Trmic, Soběnice - surface exposures; boreholes T21, T32; provided by dr. Opletal and dr. Kopecký).

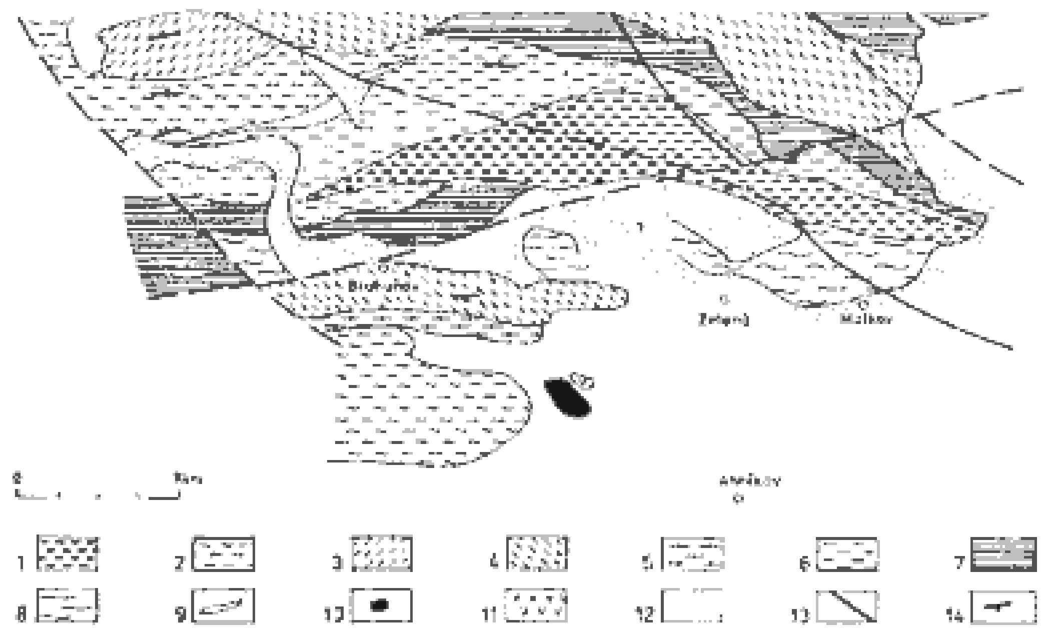

Fig. 3.2 Geological sketch of the zone Blahuňov - Málkov (area B). According to Sattran (1964), Hokr et al. (1974) and Mlčoch (1984). 1 - granulitic gneisses, 2 - orthogneisses (migmatitic), 3 - biotitic orthogneisses, 4 - medium-grained muscovitic to two-mica orthogneisses, 5 - coarse-grained augen to flaser orthogneisses, 6 - muscovite-garnet paragneisses, 7 - biotitic and two-mica paragneisses, 8 - two-mica schists to micaschist gneisses, 9 - massive gneisses ("dichte gneisse"), 10 - serpentinites, 11 - neovolcanic rocks, 12 - Pleistocene deposits, 13 - faults, 14 - foliation

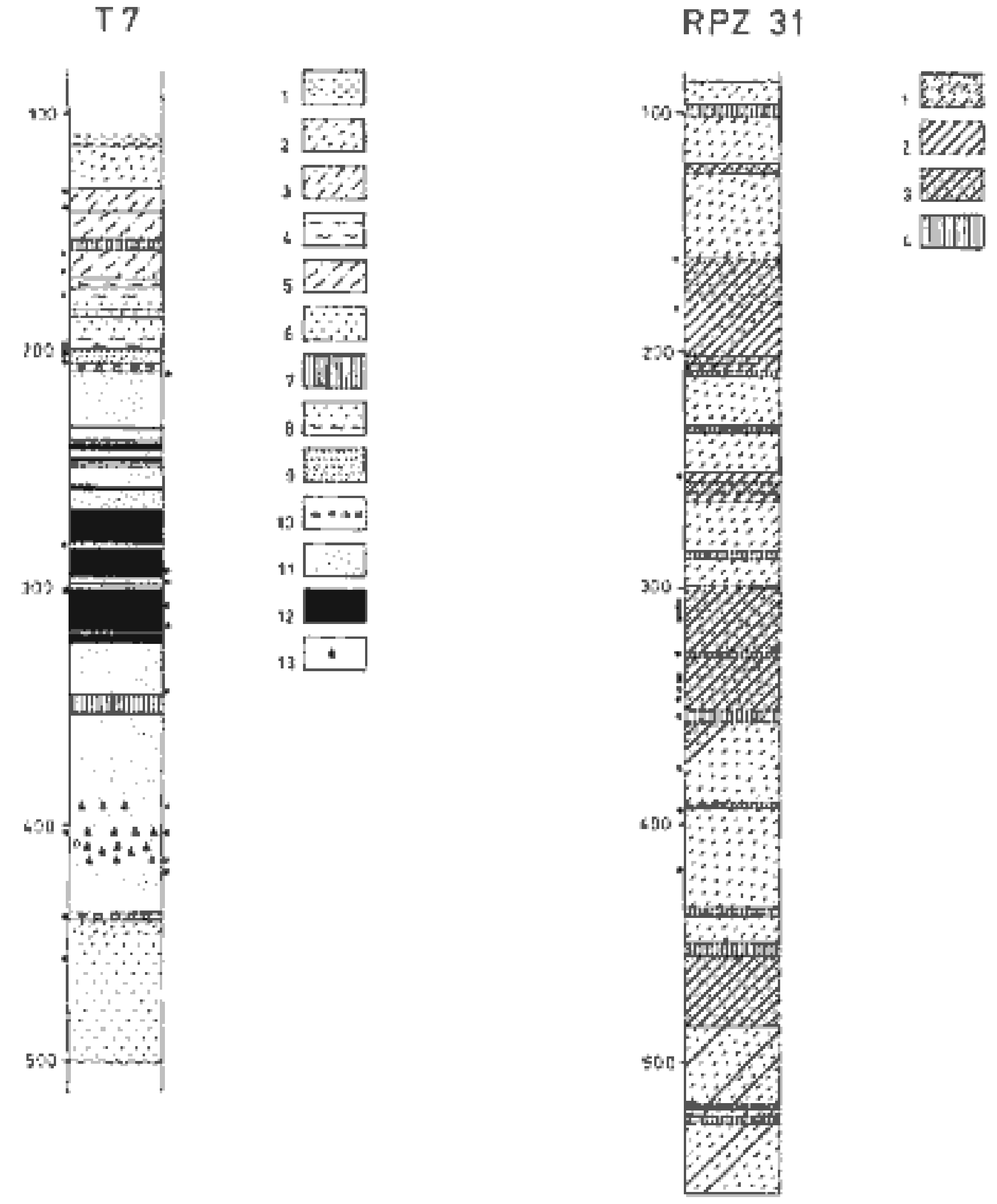

Fig. 3.3 Schematic borehole sections T7: compiled using materials of Kopecký et al. (1960), Kopecký & Paděra (1974), Fiala (1965), and own observations. 1 - Cenomanian conglomerates, 2 - weakly deformed granulite, 3 - granulitic gneiss, 4 - migmatites, 5 - alternating granulites and migmatites, 6 - white granulites, 7 - alteration zones, 8 - transition granulite-granulitic gneiss, 9 - amphibole-bearing granulites, 10 - granulite fragments, 11 - garnet lherzolite, 12 - dunite, 13 - garnet pyroxenites (fragments, thin layers), black points - sampling RPZ 31: based on documentation of dr. Chabr, Uranium Prospecting, Liberec. 1 - biotitic gneisses, locally garnet-bearing, locally augen gneisses; 2 - granulitic gneisses; 3 - biotitic gneisses with thin layers of granulitic gneisses, 4 - tectonized rocks (mylonite zones, alteration, sulphide mineralization); black points - sampling.

Borehole T7 (Fig. 3.3)

The prevailing rocks of the borehole section are acid kyanite-bearing granulites. The dip of the foliation (biotite ± muscovite, quartz) is generally 45°. Rocks are commonly heterogeneous, with alternating greyish (dark quartz) and milky or transparent more and less regular zones.

Ultrabasic body which occurs at depths of 209 - 436m consists of garnet lherzolites, dunites and subordinate garnet pyroxenites. Granulites were also found as inclusions in peridotite, and vice versa (see also Kopecký & Sattran 1966).

Borehole RPZ31 (Fig. 3.3)

The main rock type of the borehole section is represented by relatively dark garnet-biotite gneisses. Well developed foliation in biotite and muscovite (dip cca 40-45°) represents the main structural feature of these gneisses. Parallel to this foliation, 1mm - 4m thick light bands of garnet-kyanite gneisses occur.

The relation of the studied unit to the Krušné hory Mts. (KHM; Erzgebirge) crystalline complex to the NW remains unclear. The former contains abundant granulites and peridotites, while the latter is characterized mainly by amphibolite - facies metamorphism, just with some occurrences of eclogites (Klápová 1990, Schmädicke et al. 1991) and granulites associated with eclogites and garnet peridotites/pyroxenites (K. Rötzler 1992). The question of the boundary between the KHM and Ohře crystallines remains still open: does it exist, or is the latter only a facies of variable metamorphic grade facies within the unit?

Many authors suggest a close genetic link of the Ohře gneisses and granulites to migmatites and orthogneisses (so-called 'red gneisses', of magmatic origin) of the Krušné hory Mts. crystalline (e.g. Zartner 1929, Rost 1928). Differences between the two rock types were attributed to somewhat different metamorphism (Zartner 1929) or to different tectonic position of the Ohře and KHM crystallines (Sattran 1967).

In contrast to an igneous precursor, a volcano-sedimentary complex has been suggested as the granulite precursor by some authors (e.g. Zoubek 1948b). Kopecký & Sattran (1966) discuss the possibility of a migmatite complex of sedimentary origin metamorphosed in higher depth in the field of lower temperature gradient.

Concerning the position of granulite occurrences, Sattran (1967), as well as some others (e.g. Zoubek 1988), have returned to Möbus' (1964) idea of the 'Böhmische Granulitschwelle' (then called 'Ohře' or 'North Bohemian Granulite Rise', Fig. 3.1), which connects the granulite occurrences in the Ohře crystalline and the České středohoří basement.

All the concepts mentioned above are consistent with the notion of different P-T conditions being responsible for granulite occurrences within lower metamorphic units. Some authors, however, consider the Ohře crystalline complex as an older, independent unit - a Moldanubian structure (Zoubek & Škvor 1963, Chaloupský 1977).