Tracing sedimentary textures and source materials in paragneisses from the Bohemian Massif (Germany)

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Introduction

In recent years, besides petrographical parameters more geochemical data have become available for deriving characteristic provenance signatures of clastic sediments, e.g. sandstones and argillites. In high grade metasediments however, the information provided by grain size distribution and petrography of clastic components is lost, reducing the information to geochemistry and lithological associations. It is thus desirable to extract environmental information from the geochemistry of paragneisses by comparing them with low grade sediments from known tectonic environments.

Samples

A paragneiss sequence of more than 1500 m thickness and comparatively homogeneous composition was continuously cored by the German Continental Deep Drilling (KTB). KTB is situated at the western border of the Bohemian Massif within a small slice of pre-Variscan basement (Zone of Erbendorf-Vohenstrauß ZEV) that is regarded as a western outlier of the Teplá-Barrandian terrane (Franke, 1989). KTB transected a suite of paragneisses and metabasites. An amphibolite facies event dated at around 380 Ma is the most prominent metamorphic feature. With few exceptions, all KTB gneisses are of sedimentary origin. Corresponding to the mostly uniform modal composition (gt-bio-qz-pl ± ky, sil) the geochemistry of the paragneisses is quite homogeneous. Anatectic mobilisates are scarce and evidence of metasomatic overprint is missing. The ubiquitous retrogressive chloritization and sericitization did not significantly change bulk element concentrations (Müller *et al.*, 1990; Wimmenauer, 1991). O and S isotopic signatures further confirm undisturbed premetamorphic relations (Simon and Hoefs, 1993; Berner pers. comm., 1994). Hence, it can be assumed that the original sedimentary composition has mostly survived the metamorphic and deformational history of the rocks and bulk geochemistry is suitable for tracing source rock materials and paleoenvironmental characteristics.

Geochemical relationships in sediments

Main and trace element contents of clastic sedimentary rocks mirror lithological composition of the source areas, climate conditions during weathering and characteristic processes during transport and sedimentation. Easily soluble elements (e.g. Na and K) are used to delineate intensity of weathering. Refractory elements such as Y, Ti, Zr, Hf, Sc, and *REE* typically have short residence times in seawater and are generally used to characterize provenance and tectonic setting (cf. Taylor and McLennan, 1985; Bhatia and Crook, 1986; Roser and Korsch, 1986, 1988). While mature sediments show a considerable fractionation of Zr and Hf with the heavy mineral zircon into the sand fraction and of Ti, Cr, Y, Nb and other trace elements with clay minerals into the clay fraction, this differentiation is less significant in immature greywackes (McLennan *et al.*, 1990).

Geochemistry of KTB paragneisses

KTB paragneisses have high Na_2O of 2.5 to 4 wt.% and SiO_2/Al_2O_3 ratios of 3 to 7 characteristic for immature greywackes and pelitic greywackes (Table 1. (1,2). Few samples are of shale composition. CaO is typically less than 1.5 wt.% indicating the absence of carbonate in the sedimentary protolith. Based on investigations of low-grade metasediments, a SiO_2/Al_2O_3 ratio of 4 is taken as a limiting value between sandstone and argillitic protoliths (Wimmenauer, 1984; Müller, 1989). A close correlation between microscopic gneiss texture and protolith type exists for large sections of the gneiss profile. Equigranular, fine grained gneisses with weakly developed biotite foliation correspond to greywacke composition ($SiO_2/Al_2O_3 > 4$) whereas medium to coarse grained flasergneisses with pronounced segregation in biotite-rich layers and quartz-feldspar-rich layers correspond to pelitic greywackes ($SiO_2/Al_2O_3 < 4$). This micro-

TABLE 1. Average chemical compositions (1) gneisses with pelitic greywacke protolith 0–3575 m, (2) gneisses with greywacke protolith 0–3575 m, (3) aluminosilicate-free gneisses 2500–3200 m, (4) hornblende-bearing gneisses 2500–3200 m, (5) amphibolites 2500–3200 m

	(1)	(2)	(3)	(4)	(5)		(1)	(2)	(3)	(4)	(5)
n	50	54	19	22	12	n	50	54	19	22	12
SiO_2	63.90	70.90	63.60	58.80	50.10	Cu	22	15	24	28	n.d.
TiO_2	0.91	0.75	1.06	1.44	2.05	Zn	103	76	87	115	n.d.
Al_2O_3	17.95	14.51	16.18	16.11	15.33	Ga	21	16	19	55	n.d.
Fe_2O_3	7.38	5.29	7.37	8.96	11.64	Rb	91	63	81	68	52
MnO	0.13	0.09	0.12	0.16	0.20	Sr	163	168	238	296	316
MgO	2.63	1.86	2.62	3.35	4.61	Y	34	29	33	43	54
CaO	1.22	1.33	2.89	5.67	9.46	Nb	13	9	16	27	32
Na_2O	2.75	2.93	3.25	3.11	4.56	Ba	584	496	649	675	457
K_2O	3.03	2.21	2.73	2.17	1.67	La	33	28	25	37	n.d.
P_2O_5	0.12	0.10	0.15	0.26	0.42	Pb	17	16	12	10	n.d.
						Th	9	8	4	5	n.d.
						Sc	18	12	20	28	n.d.
						V	164	119	136	162	211
						Cr	119	91	108	124	175
						Co	17	8	18	24	n.d.
						Ni	41	29	51	49	74
						Zr	202	211	259	253	264

scopic observation can be generalized to a macroscopic subdivision of the gneiss sequence into an interlayering of both fabric types observable from meter to centimeter scale. The interlayering is interpreted as a relic of a turbiditic layering in the sedimentary protolith. Rb/Sr and Ti/Zr ratios confirm a slight enrichment of plagioclase and heavy minerals (zircon) in the greywacke protoliths and of clayminerals in the pelitic greywacke protoliths. Sm/Nd model ages for the sedimentary protoliths generally lie between 1.1 and 1.25 Ma (v. Drach and Köhler, 1993).

Detailed petrographic and geochemical profiling of a gneiss section with thin intercalations of amphibolites reveal sliding transitions from aluminosilicate-bearing gneiss to aluminosilicate-free gneiss and hornblende-bearing gneiss. Correspondingly, the gneiss chemistry changes from ordinary (pelitic) greywacke composition towards more basic compositions enriched in Ti, Fe, Mg, Ca, Na, Sr, V, Cr, Co, and Ni (Table 1. (3,4)). The section is interpreted as a volcano-sedimentary sequence with varying influx of basic debris into the sediment. The relative amount of local input of basic debris in comparison with the sedimentary 'background' of greywacke and pelite can be modeled.

A slight enrichment in Fe, Mn, Mg, Ca, V, Cr, Co, and Ni is also observed in paragneisses within a second variegated section characterised by a pronounced alkali-basaltic chemistry of amphibolites and additional meta-trachytes and calcsilicatic layers. Again, the more basic gneiss chemistry is ascribed to an increased input of mafic (?volcaniclastic) debris, but the gneisses give higher Sm/Nd model ages (> 1250 Ma, *v*. Drach and Köhler, 1993), which must be due to an additional sedimentary input from older terrains.

Environmental setting of sedimentation

According to the discrimination diagrams suggested by Bhatia and Crook (1986) for the determination of tectonic environment of sediments and according to multi-element comparison with average sediment compositons from different tectonic settings (Floyd *et al.*, 1990), KTB paragneisses are best compared with greywackes from active continental margin settings or from island arcs on continental crust (Müller and Mingram, 1993). Due to the lack of reliable data for the sedimentation age of the KTB metasediments the general geotectonic relations between ZEV, Teplá-Barrandian, Saxothuringian, and Moldanubian tectonostratigraphic units is still under debate. Comparison of metasediment geochemistry from all units points to a good agreement between ZEV and Teplá-Barrandian while adjacent Moldanubian and – to a much higher degree – Saxothuringian metasediments represent more mature deposits influenced by large amounts of quartzose to felsic debris.