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Ferrosyenites from the Cuddapah Intrusive Province (CIP) of Peninsular India

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Abstract: *Ferrosyenites, which are unique rock types, are emplaced in Cuddapah intrusive province of peninsular India. These rare rock types are found to emplace at Gundlapalle and Gokanakonda in the Guntur District and at Uppalapadu in the Prakasam District of Andhra Pradesh. These syenites show considerable variation in mineralogical and geochemical composition. For an example the Gundlapalle syenites are devoid of olivine whereas in the other plutons olivine is essentially present with or without quartz. Normatively, these syenites are characterised by quartz, hypersthene or quartz+hypersthene combination. There are no indications of alkaline character in these rocks. As the name of these rocks indicates Mg is found to depleted whereas Fe+2 is enriched due to the presence of ferrohedenbergite and fayalite. The rocks are derived from anhydrous gabbroic magma which is evidenced by the absence of hydrous ferromagnesium minerals and the magma is subjected to closed system fractionation. The ferrosyenite from Uppalapadu alkaline complex is dated by U-Pb Zircon as 1352 Ma.*

Key words: *Ferrosyenites, Cuddapah intrusive Province*

1. Introduction

Ferrosyenites are very rare in geological occurrences, and therefore they are very sparingly found. In the whole of India only four ferrosyenite plutons are found, one from Sivamalai in Tamilnadu and rest are from Gundlapalle and Gokanakonda in Guntur district and Uppalapadu in Prakasam district of Andhra Pradesh. Geologically speaking the Sivamalai pluton occurs in the southern peninsular alkaline-carbonatite province and those at Gundlapalle, Gokanakonda and Uppalapadu are from Cuddapah intrusive province (CIP) of Andhra Pradesh. It may be mentioned here that Prakasam alkaline province first proposed by Leelanandam (1981, 1989) was subsequently renamed as Cuddapah Intrusive Province by Madhavan et al. (1995) by including non-alkaline intrusives like gabbros and granitoids.

The Gundlapalle ferrosyenite is mesocratic and medium grained, the ferrosyenite body is found emplaced with sharp contact between peninsular gneisses, quartzite and Narji lime stones. The ferrosyenites from CIP exhibit considerable mineralogical, geochemical and geological variations. An important observation as far as the Gundlapalle syenite is concerned is the presence of nontronite mineral which is an altered product of ferrohedenbergite formed due to hydrothermal alteration (Madhavan et.al., 1994).

Based on mineralogical criteria the Gokanakonda ferrosyenites can be differentiated into two types i) fayalite ± clinopyroxene syenite and ii) fayalite ± quartz syenite. Both these rock types are medium grained mesocratic, which are more prominently exposed at Gokanakonda (fayalite ± clinopyroxene syenite) but less prominently at puvvada (fayalite ± quartz syenite), with Gundlakamma River in between. The Uppalapadu ferrosyenites show a mesocratic appearance and are medium to coarse grained. The pluton has a sharp contact with the surrounding olivine gabbronorite and hornblende syenite. These ferrosyenites are now very scarcely available due to large scale quarry. The Uppalapadu ferrosyenite is also found as enclaves within the Errakonda hornblende syenite at Obachetta palem on the western side of Ramatheertham reservoir. The model compositions of these interesting rock types are listed in Table 1, along with certain relevant information in Table 2. The geological map showing the distribution of these syenites can be found in Figure 1.

Table 1: *Modal compositions (vol%) of the ferrosyenites of CIP*

Minerals	GP-6	GP-IV	GP-II 1	GK-4	GK-2	PV-8	PV-1	EKP-2	EKP-3	EKP-7
Quartz	1.0	3.8	5.5	2.0	1.5	18	17	1.5	2.0	1.0
K-Feldspar	83	80	82	72	75	65	67	69	68	67
Plagioclase	-	-	-	9.0	7.2	7.6	6.5	11	9.0	12

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Olivine	-	-	-	4.5	4.2	3.5	3.7	1.9	1.5	0.9
Clinopyroxene	7.2	4.0	3.0	6.5	7.0	-	-	8.0	10	2
Amphibole	3.1	2.5	2.0	1.5	1.2	-	-	3.2	3.0	2.5
Garnet	-	-	-	-	-	-	-	-	-	8.0
Biotite	0.2	0.1	0.1	3.0	2.5	0.1	0.1	0.8	0.5	4.0
Nontronite	-	4.0	4.5	-	-	-	-	-	-	-
Magnetite	4.0	2.5	1.9	1.0	0.5	4.0	4.9	1.0	1.5	1.0
Sphene	0.5	-	-	-	-	-	0.2	-	-	-
Calcite	0.2	-	-	-	-	-	-	-	-	-
Apatite	0.2	0.1	-	0.4	-	-	-	2.0	1.9	1.5

GP-Gundlapalle. GK-Gokanakonda (FC). PV- Puvvada (FQ). EKP-Uppalapadu ferrosyenite

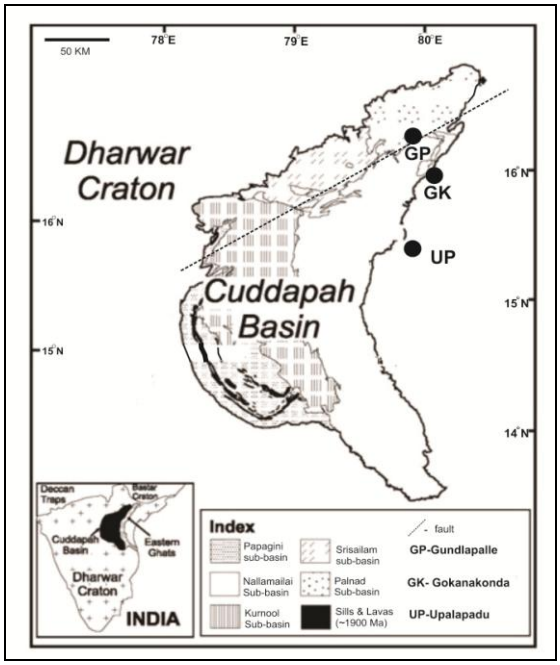

Fig 1: *Distribution of ferrosyenites in CIP*

Gundlapalle Ferrosyenite

The Gundlapalle pluton is found near Piduguralla (Lime city) in the Guntur district of Andhra Pradesh. It is located towards the northern part of the Cuddapah intrusive province. This sub-alkaline syenite pluton occurs as four mounds, which are not so prominently exposed and it has an elliptical outline, covering an area of about 3 km^2. The pluton has a sharp contact with discrete occurring and widely different lithological units such as granite (Dharwars), Panyam quartzites and Narji limestones belonging to (Palnad sub-basin) Kurnool group (Fig.2a.b). There is an overall conformity in the planar structures (foliation/bedding plane) of the adjoining country rock (granites, quartzites, and limestones) with the boundary of the plutons, implying that the syenite was emplaced by a simple mechanism of dilation (Madhavan et al., 1994). The medium grained mesocratic rock is composed of ferrohedenbergite, alkali feldspar (microcline mesoperthite, 80-83 vol %) and hornblende as essential minerals and sphene, quartz, biotite, calcite and rutile as accessory minerals (Table 1). These rocks conspicuously show an extensive hydrothermal alteration of ferrohedenbergite to nontronite, which appears in golden brown colour within the skeletal pyroxene crystals (Fig 3a. b).

Gokanakonda Ferrosyenites

The ferrosyenites are hosted by Settupalle alkaline complex which is sub-oval in shape with an extent of 40 km^2. The silica oversaturated and silica undersaturated Settupalle alkaline pluton from the Cuddapah intrusive province is confined to an extremely narrow linear belt which is close to the known basement fracture zone (Leelanandam 1989). The Gokanakonda (GK) subalkaline ferrosyenites occupy an area of 5 km^2 and are found towards the southern marginal portion of the Settupalle alkaline complex. Based on mineralogy, the ferrosyenites can be differentiated into two types i) fayalite ± clinopyroxene syenite and ii) fayalite ± quartz syenite. Both these rock types are mesocratic in nature with medium to coarse grained hypidiomorphic texture which is more prominently exposed at Gokanakonda, and less prominently at puvvada (PV). The fayalite ± clinopyroxene syenite is found on the east and fayalite ± quartz syenite on the west of Gokanakonda village with the Gundlakamma River which forms the dividing line between these two rock types.

The contact between fayalite ± clinopyroxene syenite and gabbro on the eastern side and the contact between fayalite ± quartz syenite and the Gabbro on the western side are sharp (Srinivasan et al., 1990). The fayalite ± clinopyroxene (FC) syenite is composed of alkali feldspars (72-75 vol %), clinopyroxene and fayalite as essential minerals and plagioclase, ferrohastingsite, biotite as accessory minerals. The fayalite ± quartz (FQ) syenite is composed of alkali feldspar (65-67 vol %) (Table 1) and quartz as essential minerals and fayalite, amphibole as accessory minerals (Fig 3 c.d.e.f).

Table 2: *Ferrosyenites from Cuddapah intrusive province and their mineralogical, lithological characters*

Area	Sl.No	Location	Rock type	Mineral assemblage	Age	Associated rocks
CUDDAPAH INTRUSIVE PROVINCE (Andhra Pradesh)	1	**GUNDLAPALLE** {16°24'N :79°52' E}	Ferrosyenite	Ferrohedenbergite Alkali Feldspars Hornblende, Nontronite , Quartz , Biotite, Rutile , Calcite, Magnetite.	NA	Granites, Quartzite. Limestones
	2	**GOKANAKONDA (SETTUPALLE COMPLEX)** {16°01' N: 79°52' E}	i) Fayalite ± clinopyroxene syenite	Alkali feldspars , Plagioclase, Fayalite, Titanoaugite/Ferroaugite Ferrohastingsite, amphibole , quartz, Biotite, Opaques,	NA	Gabbro, Hornblende Syenite, Amphibolite, Granite Gneiss, Quartz Syenites, Nepheline syenite, Mafic Rocks.
			ii) Fayalite ± quartz syenite.	Alkali Feldspars, Fayalite, Quartz, amphibole, Biotite, Opaques,	1352 Ma	
	3	**UPPALAPADU PLUTON** **{**$15^0$35'N:$79^0$47'E}	Ferrosyenite	Pyroxenes, fayalite, Perthitic K-Feldspar Plagioclase, Fe-augite, Ferrohedenbergite and trace amount of inverted pigeonite, garnet, apatite, calcite.		Olivine gabbronorite, Hornblende Syenites, Nepheline Syenites, Anorthosites, Quartz Syenites,

Uppalapadu Ferrosyenite

The Uppalapadu (UP) alkaline complex is located on the eastern side of the Chimakurthy olivine gabbronorites of Cuddapah intrusive province which are spread in an area of 30 km^2. The pluton is chiefly composed of nepheline syenite, hornblende syenite, ferrosyenite, anorthosite, olivine clinopyroxenite and olivine gabbronorite. The ferrosyenite has sharp contact with Olivine gabbronorite on the eastern side and hornblende syenite on the western side (Krishna reddy et al. 1997) (Fig.2e). The U-Pb Zircon age of the ferrosyenite from Uppalapadu alkaline complex is 1352 Ma (Vijaya Kumar et al.2007). The Medium to coarse grained ferrosyenite shows hypidiomorphic texture and is mainly composed of perthitic K-feldspar (67-69 vol %) (Table 1), plagioclase, fayalite, ferrohedenbergite, ferroaugite, ferrosilitic orthopyroxene, interstitial quartz as essential minerals and inverted pigeonite, almandine rich garnet, apatite, calcite and opaques as accessory minerals (Fig.3g.h).

Summary and Conclusion

Extensive field study has been conducted to investigate the mineralogical and geochemical characteristics of these rocks. A number of representative samples were collected and their thin sections are made to study their petrographic similarities and dissimilarities. At Gundlapalle, perthitic laths can be noticed in the ferrosyenite at a place near the north eastern part of pluton. Sharp contact between ferrosyenites and Panyam quartzites was observed on the western side of the pluton (Fig.2b). The ferrosyenites exposed at Gokanakonda are represented by FC-syenite (Fig.2c). At puvvada the FQ-syenites are exposed as small outcrops, which show spheroidal weathering (Fig.2d). Most of the Uppalapadu ferrosyenite is quarried and the dumps cover the remaining outcrop. A narrow gap was found in between gabbroic dump and hornblende syenite where the ferrosyenite is exposed (Fig.2e). Sharp contact has been observed between hornblende syenite and ferrosyenite in the field, remaining ferrosyenites of the area are available in the form of enclaves within the hornblende syenite towards Obachetta palem (Fig.2f). Megascopically the rocks are mesocratic and medium to coarse grained in nature. Equigranular hypidiomorphic texture is shown by all the three ferrosyenite plutons. Mineralogically ferrohedenbergite is common in all the ferrosyenites but fayalite, ferrosilitic orthopyroxene, inverted pigeonite and ferroaugite are not present in the Gundlapalle ferrosyenite. Garnet is present in the Uppalapadu ferrosyenite only (Table 2). It should be mentioned here that the Gundlapalle ferrosyenite shows extensive hydrothermal alteration of ferrohedenbergite to nontronite which appears in golden brown colour within the skeletal pyroxene crystals.

***Table 3**. Major oxides data (Wt%) of Gundlapalle, Gokanakonda and Uppalapadu ferrosyenites*

Oxides	GP-30	GP-38	ST17	ST16	74	39
SiO_2	61.05	64.27	59.50	63.73	59.14	59.93
TiO_2	0.23	0.23	0.86	0.47	0.98	0.38
Al_2O_3	18.15	15.12	16.62	16.87	18.55	18.07
Fe_2O_3	3.00	3.72	0.78	0.65	1.99	1.63
FeO	4.00	3.10	5.92	3.17	4.88	4.17
MnO	0.15	0.14	0.17	0.10	0.13	0.12
MgO	0.20	0.26	0.44	0.27	0.61	0.36
CaO	2.60	2.25	3.48	2.15	3.19	2.58
Na_2O	5.25	5.33	5.10	5.46	4.65	5.54
K_2O	5.05	5.05	5.67	6.96	6.16	6.02
P_2O_5	0.13	0.13	0.34	0.14	0.30	0.10
LoI	0.45	0.78	-	-	-	-
Total	100.26	100.38	98.88	99.97	99.70	99.87
CIPW Norm						
q	3.74	9.67	0.00	0.49	0.00	0.00
or	29.84	29.84	33.51	41.13	36.40	35.58
ab	44.42	45.10	43.16	46.20	39.35	43.40
an	11.04	2.42	5.71	0.97	11.55	6.66
di	0.89	6.10	8.18	7.68	2.00	6.67
wo	0.00	0.35	0.00	0.00	0.00	0.00
hy	4.80	0.00	1.05	1.36	4.03	0.00
ol	0.00	0.00	3.74	0.00	1.82	3.28
mt	4.35	5.39	1.13	0.94	2.89	2.36
il	0.44	0.44	1.63	0.89	1.86	0.72
ap	0.31	0.31	0.81	0.33	0.71	0.24
DI	78.00	84.62	76.66	87.82	75.75	78.97

Gundlapalle GP-30, 38 (Madhavan et.al.1994). Gokanakonda, ST17- FC-fayalite clinopyroxene syenite. ST16-FQ-fayalite quartz syenites (Leelanandam.et.al.1989). Uppalapadu 74, 39 (Krishna reddy et al. 1997). DI-Differentiation Index of Thornton and Tuttle (1960).

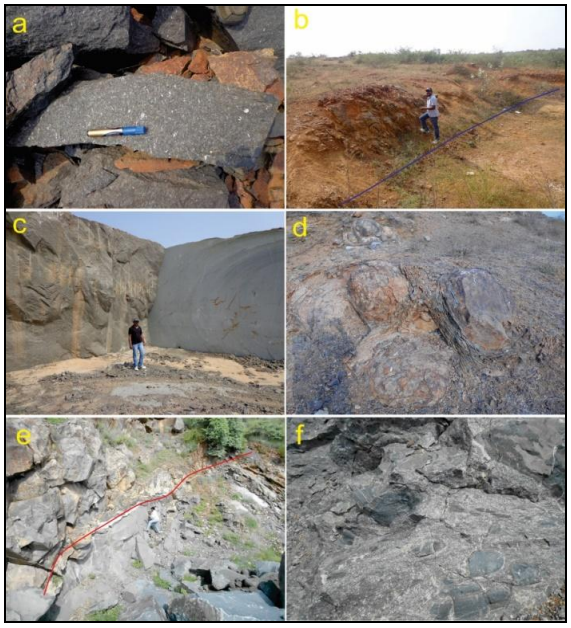

***Fig 2.** Field photographs of CIP ferrosyenites*

(a) Gundlapalle (GP) syenite showing Perthite laths. (b) Sharp contact between ferrosyenite and quartzite. (c) Quarry of fayalite clinopyroxene syenite from Gokanakonda (GK). (d) Fayalite quartz syenite showing spheroidal weathering (PV). (e) Sharp contact with Uppalapadu (UP) ferrosyenite and hornblende syenite. (f) Ferrosyenite enclaves within the hornblende syenite.

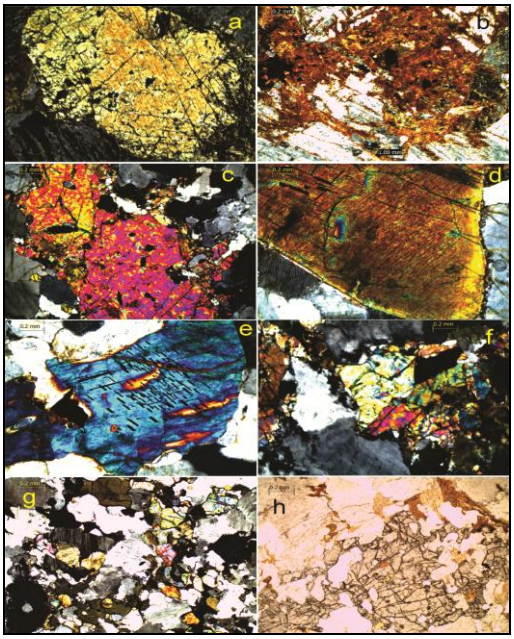

***Fig 3.** Photomicrographs of CIP ferrosyenites (a)Ferrohedenbergite associated with alkali feldspars (GP). (b) Nontronite within the skeleton pyroxene, associated with magnetite (GP). (c) Anhedral olivine in FQ syenite (GK). (d) Inverted pigeonite (GK). (e) Blue coloured amphibole (GK). (f) Olivine associated with magnetite in FQ syenite (PV). (g) Olivine associated with Perthite (UP). (h). Garnet in PPL (UP)*

The published geochemical data of ferrosyenites are given in Table 3. Based on the presence of the normative hypersthene and quartz, these rocks are classified as subalkaline and further based on silica percentage they are classified as silica saturated group (SiO_2 wt% 59.14 to 64.27). The ferrosyenites are highly depleted in Mg content and enriched in Fe^{+2}, which is similar to some of the ferrosyenites of the world as found in America, Greenland, Europe and China. These rocks are supposed to have formed from a gabbroic magma, which is evident by the field setup. The absence of hydrous ferromagnesium minerals indicates that the magma underwent a closed system fractionation. An analogy for the petrogenesis of Gokanakonda and Uppalapadu ferrosyenites can be drawn from the petrogenesis of the ferrosyenites of the famous plutons of the world such as Kiglapait Intrusion (Labrador- America), Kûngnât Fjeld Complex of Greenland, Mutěnin Pluton of Bohemian Massif (Europe), Western Baima Igneous Complex (Panxi Region) of China (Barmina et al., 2001; Morse 1980. Stephenson et al., 1982. Zulauf et al., 2002. Gregory Shellnutt et al., 2008), wherein the ferrosyenite magma evolved from gabbroic magma parentage.

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References

[1]Babu. E.V.S.S.K.. Leelanandam. C.. (1993). Fossil pigeonites and exsolution features in pyroxenes from ferrosyenites of South India. Jour. Geol. Soc. Ind. v. 41. pp. 351–359.

[2]Barmina G.S. and A. A. Ariskin (2002) Estimation of Chemical and Phase Characteristics for the Initial Magma of the Kiglapait Troctolite Intrusion. Labrador. Canada Geochemistry International. v. 40. No. 10. pp. 972–983.

[3]Bhattacharyya. S.. Bose. S.K.. Dutta. H.S.. (1981). Petrology of the alkalic suite of Errakonda hill near Chimakurti. Prakasam District. Andhra Pradesh. Indian Journal of Earth Sciences. v. 9.pp.84–89.

[4]Bhattacharyya.S. and P. Sengupta (2014) Modeling of dissolution–re precipitation ion-exchange reactions for the development of flame perthite in a suite of sheared alkaline rocks: an example from Chimakurthy. Eastern Ghats. India. Mineralogical Magazine. Oct 2014.v.78 (5). pp.1301–1323.

[5]Bose. M.K.(1968) Mineralogical Study Of Striped Pyroxene In Syenitic Rocks Of Sivamalai. South India. The American Mineralogist. v. 53. March April. 1968.

[6]Gregory Shellnutt J. Mei-Fu Zhou (2008) Permian. rifting related fayalite syenite in the Panxi region. SW China. Lithos v.101. pp.54–73.

[7]Krishna Reddy. K. Ratnakar. J. Leelanandam. C.. (1998). A petrochemical study of the Proterozoic alkaline complex of Uppalapadu. Prakasam Province. Andhra Pradesh. India. Jour.Geol.Soc.Ind. v.52. pp.41–52.

[8]Leelanandam. C. (1981). Some observations on the alkaline province in Andhra Pradesh. 20 Sep 1981, v.50 No.18

[9]Leelanandam. C. (1989). The Prakasam Alkaline Province in Andhra Pradesh. India. Jour.Geol.Soc .Ind.v.34.pp. 25–45.

[10]Leelanandam. C. (1993a). Eulitic and ferrosilitic orthopyroxenes from Ferrosyenites of south India: evidences for a high temperature crystallization and tholeiitic parentage. Current Science. v.64. pp.729–735.

[11]Leelanandam. C. (1993b). Almandine-rich garnets from fayalite–ferrosilite–quartz-bearing ferrosyenites in the Prakasam District of Andhra Pradesh. India. Jour. Geo. Soc. Ind. v .41. pp.437–443.

[12]Leelanandam. C. (1994). Na-poor ferro-augites and ferro-hedenbergites from ferrosilite-bearing ferrosyenites of the Prakasam District in Andhra Pradesh. India: further evidences for a tholeiitic parentage. Jour. Geol. Soc. Ind.v. 44. pp.7–16.

[13]Leelanandam. C. (2003). Extremely Iron-Rich Olivines from ferrosyenites of the Prakasam District. Andhra Pradesh with Petrogenetic comments. Jour. Geol. Soc. Ind. v.61. pp.607-611.

[14]Madhavan, V., Rao, J.M., Srinivas, M., Natarajan, R. and Sayeed, A., (1994). Petrology and petrogenesis of syenites from the Cuddapah basin, Andhra Pradesh. Jour. Geol. Soc. Ind. v.43(3), pp.225-237.

[15]Madhavan, V., Rao, J.M., Rao, N.C. and Srinivas, M., (1995). Multi-faceted manifestations of an intrusive province around the intracratonic Cuddapah basin, India. Magmatism in Relation to Diverse Tectonic Settings, pp.93-105.

[16]Madhavan.V. (2001) Rare alkaline rocks from Andhra Pradesh. Southern India. Journal of Asian Earth Sciences. v. 19. pp. 321-332.

[17]Madhavan.V. (2004) Continental Alkaline Magmatism Vis-À-Vis The Indian Subcontinent: A Documentary Profile Jour. Geol. Soc.Ind.v.63.pp.271-281.

[18]Morse.S.A.(1980) Kiglapait Mineralogy II: Fe-Ti Oxide Minerals and the Activities of Oxygen and Silica. Journal of Petrology. v.21. Part 4. pp. 685-719.

[19]Srinivasan.T.P and Natarajan.R (1990) Significance Fayalite (± Quartz) Assemblages on Gokanakonda Syenite. Prakasam district. Andhra Pradesh. Jour.Geol.Soc.Ind.v.36. pp.143-153.

[20]Stephenson.D.(1982) Ferromagnesian silicates in a differentiated alkaline complex: Kungnat Fjeld. South Greenland Mineralogical Magazine. Sep. v.46. pp. 283-300.

[21]Zulauf. G. C. Bues · W. Dörr · Z. Vejnar (2002) 10 km Minimum throw along the West Bohemian shear zone: Evidence for dramatic crustal thickening and high topography in the Bohemian Massif (European Variscides) Int Jou. Earth Sci (Geol Rundsch) 91:850–864.