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The petrology and geochemistry of Koriga iron-formation, N.W. Nigeria

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Abstract

The Koriga iron-formation is located in the Kushaka Schist belt of north-western Nigeria. It occurs as thin intercalations in the phyllites and pelitic schists which also contain concordant bands of amphibolite. A Kibaran (ca 1100 Ma) age has been suggested for the rocks of the Kushaka Schist belt which have been intruded by granitic rocks dated ca 600 Ma.

The iron-formation consists dominantly of silicate minerals: grunerite, spessartine-rich almandine garnet, quartz and some martite, but occassional thin, more oxide-rich bands with martite, magnetite and silicate minerals also occur. Fe_2O_3 (total iron content varies from 26.20 to 34.05% and SiO_2 content from 46.61 to 62.51% in the silicate-rich rocks. The oxide-rich bands are richer in total iron with Fe_2O_3 contents of about 59%. High values of Al_2O_3 (3.87–9.69%) and MnO (1.30 to 7.62% characterise the Koriga iron-formation.

Introduction and geological setting

The Koriga Iron Formation is part of the Kushaka Schist Belt located in northwestern Nigeria (Figs 1 and 2). This iron formation was formerly described as the Koriga Ferruginous Quartzite Member of the Kushaka Schist Formation by Truswell & Cope (1963). The Kushaka Schist Belt comprises mica schists, phyllites, slates, amphibolites and iron-rich rocks.

This schist belt occupies synclinorial keels in the basement of gneisses and migmatites which all together have been intruded by Pan African granitic rocks, dated ca 600 Ma (Truswell & Cope 1963, Grant 1978, Turner 1983). Grant (1987) and Turner (1983) have suggested a Kibaran (ca 1100 Ma) age for the rocks of the Kushaka Schist Belt on the basis of ages of 1315 ± 15 and 1159 ± 70 Ma obtained from granitic gneisses adjacent to the belt (Grant et al. 1972).

The Koriga Iron Formation occurs as discontinuous 20–100 cm thick bands intercalated with the mica schists. Because of poor exposure, complex deformation and lack of way-up indicators, the stratigraphic succession is difficult to establish. However, in some areas a local succession may be recognised going from mica schists at the bottom to iron-formation and finally phyllites and slates at the top. (Truswell & Cope 1963). Locally, non-ferruginuous quartzite bands are also intercalated with the schists and phyllites. Also concordantly intercalated with the schists and phyllites are bands of amphibolite, 50–500 cm thick, consisting of hornblende, plagioclase, quartz and sphene with or without epidote.

Grant (1978) has recognised four generations of minor structures in the Kushaka belt. These include a sequence of folds (F1 to F3) followed by locally-developed crenulation cleavage and associated folds. The tight to isoclinal F2 and open F3 minor folds are the most widely distributed minor structures and are associated with major folds, the

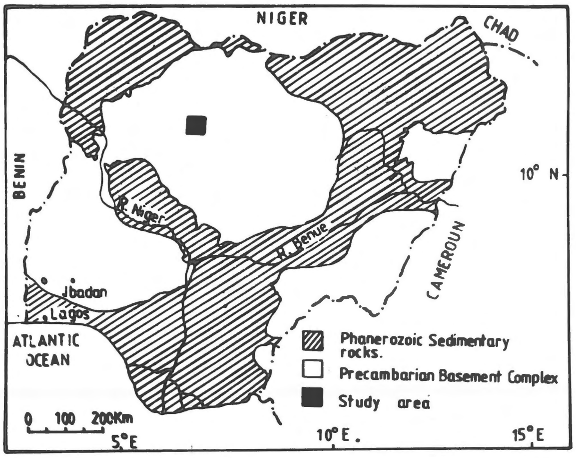

Fig. 1. Location of Kushaka Schist belt in N.W. Nigeria.

F2 Gwapada-Akache Synform and the F3 Masaka Antiform, respectively (Fig. 2; Grant 1978). The Koriga iron-formation occurs on the flanks of the major Gwapada-Akache Synform.

The area has also been affected by late dextral transcurrent faults, notably the Kalangai fault which has a displacement of about 12 km (Truswell & Cope 1963).

Petrography

The Koriga iron-formation consists dominantly of bands rich in silicate minerals but also locally contains thin 5–10 cm thick bands rich in oxide minerals in which hematite-(martite-)rich bands alternate with garnet- and grunerite-rich ones.

The silicate mineral-rich rocks are generally massive and poorly banded. They generally contain grunerite, garnet, hematite (martite), secondary minnesotaite and goethite.

Grunerite occurs in several textural varieties which include prismatic, acicular and tabular. Prismatic grunerite is more common in the more typically foliated rocks of the iron-formation where it occurs as prisms 0.5–1 mm long, aligned parallel to the foliation (Fig. 3). It is commonly intergrown with garnet and martite. Tabular grunerite occurs

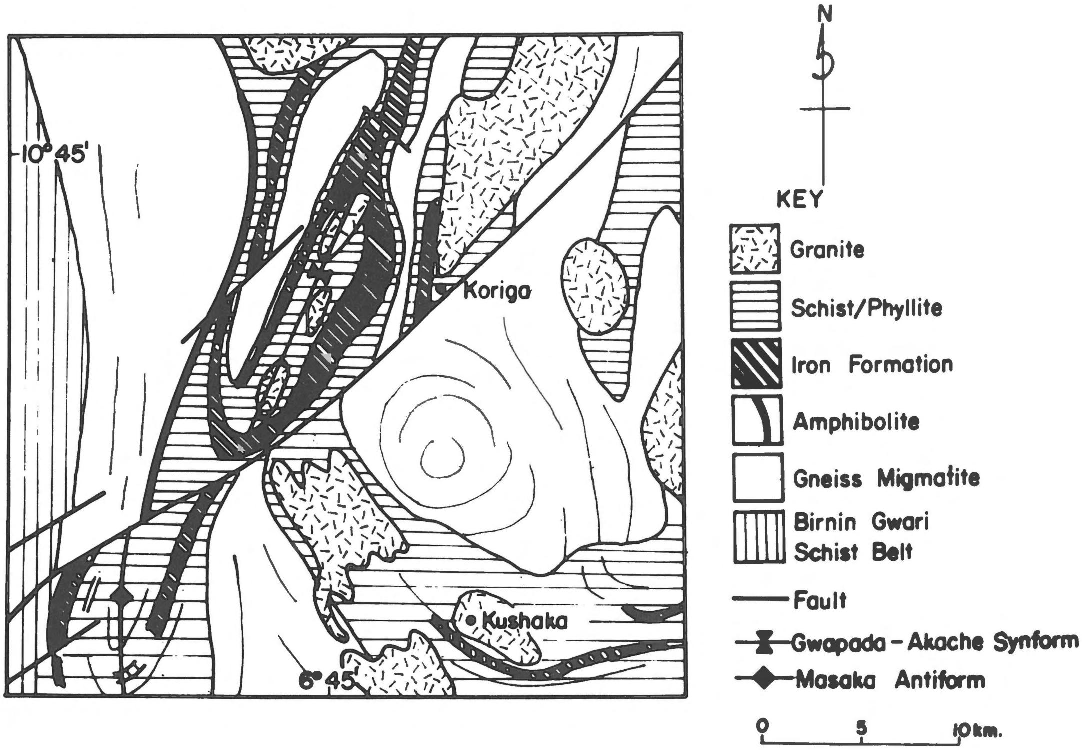

Fig. 2. Geological map of Kushaka Schist belt. (After Turner 1983).

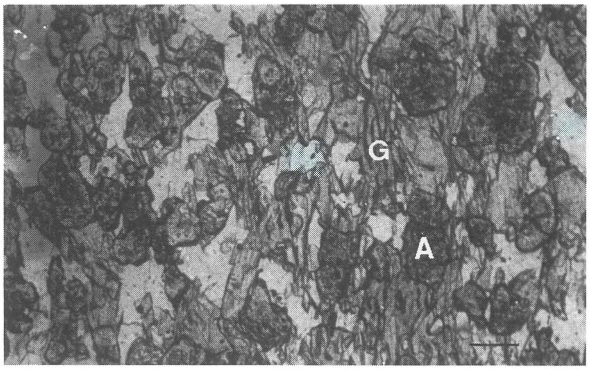

Fig. 3. Photomicrograph of Koriga iron-formation. Almandine garnet (A) intergrown with grunerite (G) and quartz (grey). Plane polarised light. Scale bar = 0.1 mm.

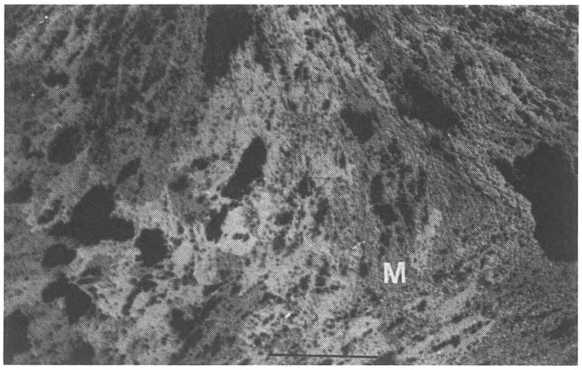

Fig. 4. Photomicrograph of oxide-rich band in iron-formation. Hematite (martite) replacing magnetite (M) Polished section Plane Polarised light. Scale bar = 0.1 mm.

as coarse, often variably oriented, 1–2 mm long grains and is more common near the late granitic intrusions. They are therefore believed to be recrystallised grains under higher temperature contact metamorphic conditions, and contain inclusions of garnet, quartz and hematite (martite). Acicular grunerite occurs as tiny grains about 0.5 mm long which generally occupy interstices between garnet porphyroblasts. Grunerite commonly shows polysynthetic twinning and is occasionally partially replaced by fibrous minnesotaite.

Garnet (almandine) occurs as fine-to coarse-grained crystals. Coarse-grained garnet, 1–2 mm in diameter, is commonly poikiloblastic with inclusions of hematite (martite), grunerite and quartz. It is typical of the aureole of the Pan-African granites. Fine-grained garnet 0.1–0.5 mm in diameter is commonly intergrown with grunerite (Fig. 3). Garnet is occasionally partially altered to chlorite and hematite.

Hematite (martite) is the dominant mineral in the occasional thin oxide-rich bands (Fig. 4) where it is commonly seen enclosing relict magnetite. Hematite occassionally shows cross-hatched martitisation lamellae. Hematite is occassionally partially replaced by goethite.

Quartz occurs as tiny grains 0.1–0.5 mm in diameter interstitial to the other minerals in the rocks.

Geochemistry

Seven samples of the Koriga iron-formation were analysed for major and trace elements by XRF spectrometry. The results are presented in Table 1.

Major elements

The major element composition is presented in Table 1. The total Fe content expressed as Fe_2O_3 ranges from 26.20 to 34.05% while the SiO_2 content varies from 46.61 to 62.51% in the silicate-rich rocks. The thin iron-rich bands are however richer in total Fe as Fe_2O_3 (ca 59%) and poorer in SiO_2 (Table 1). Generally the major element composition of the Koriga iron-formation is within the range of values for these elements in banded iron formations determined by Gole & Klein (1981; Fig. 5).

The Koriga is, however, characterised by higher values of MnO and Al_2O_3 and by lower average values of MgO and CaO compared to their average values in banded iron formations given by Gole & Klein (1981). The Al_2O_3 content of the Koriga iron-formation ranges from 3.87 to 9.69% and its MnO content from 1.30 to 7.62% whereas its MgO content varies from 0.41 to 1.98% and its CaO content from 0.41 to 1.66%.

The major element composition of the Koriga iron-formation is generally similar to that of the aluminous iron-formation reported by Dymek & Klein (1988) except that the Koriga samples are relatively enriched in MnO but depleted in MgO and CaO.

Trace elements

Generally the concentrations of trace elements in the Koriga iron-formation are low (Table 1). The exceptions are Pb and Cu which are relatively high. Particularly the concentrations of the transition elements are low indicating that the iron enrichment in the iron-formation was not associated with enhanced values of other transition elements.

These concentrations are however comparable with 'silicate facies' iron formations such as those of Redstone, Canada (Robinson 1984) and Isua, Greenland (Dymek & Klein 1988).

Mineral chemistry

Some of the minerals present in the Koriga iron-formation were analysed by electron microprobe at the Institute of Mineralogy and Petrology, University of Gottingen, Germany (Table 3).

The grunerites are iron-rich with 37.20 to 44.99% FeO total, while the garnets are spessartine-rich almandines with 18.40 to 31.10% mol. spessartine. The stabilisation of garnet at the greenschist facies conditions of this iron formation is due to this high MnO content.

Discussion

The aluminous nature of the Koriga iron-formation is reflected in the high modal almandine garnet content (cf Dymek & Klein 1988) and the stabil-

Table 1. Major and trace element chemistry of the Koriga iron formation

	6	8	9	11	12	4	5
SiO_2 (%)	46.61	51.31	51.18	59.13	62.51	20.05	19.86
TiO_2	0.28	0.39	0.22	0.33	0.11	0.41	0.22
Al_2O_3	7.86	9.69	5.99	7.30	3.87	7.81	7.56
Fe_2O_3*	34.05	27.30	32.24	26.97	26.20	58.90	59.62
MnO	6.22	7.62	6.12	1.30	3.19	6.51	6.32
MgO	1.98	1.62	1.96	1.94	0.64	nd	0.12
CaO	1.19	1.18	0.99	1.66	0.74	0.41	0.42
Na_2O	nd	nd	nd	nd	nd	nd	nd
K_2O	0.16	0.16	nd	0.17	0.15	0.22	nd
P_2O_5	0.10	0.09	0.12	0.12	0.17	0.15	0.12
LOI	1.52	0.53	1.45	0.88	2.21	4.51	5.16
Total	99.97	99.89	100.27	99.80	99.79	98.97	99.4
Rb (ppm)	17	109	4	3	2	3	1
Sr	21	23	20	21	35	66	68
Y	33	44	36	20	40	37	43
Zr	82	84	69	78	44	64	70
Nb	15	17	15	114	11	19	20
Cr	75	66	76	71	46	120	110
Ni	50	39	47	37	31	102	94
Cu	38	96	82	64	33	80	83
Ga	9	10	12	4	8	5	5
Zn	62	64	10	57	61	33	36
V	57	54	59	49	37	95	74
Pb	26	35	38	26	34	65	59
Th	8	2	2	3	1	8	2

Fe_2O_3*: Total Fe; nd: not detected; Samples 4 & 5: oxide-rich bands.

isation of garnet at the greenschist facies conditions of the iron-formation is due to its appreciable content of MnO (Table 2). It has been suggested that the high Al_2O3 content of some iron-formations is due to the admixture of some fine-grained clastic material with the chemical precipitates (Govett 1966, Robinson 1984, Dymek & Klein 1988). This situation would have been highly likely with regard to the Koriga iron-formation which occurs as thin intercalations within aluminous phyllites and pelitic schists.

The close association of the iron-formation with chemically and texturally mature sediments now represented by the phyllites and pelitic schists suggests derivation of the iron and manganese from a nearby deeply-weathered terrain (Govett 1966, Goldich 1973). However, the presence of intercalated bands of amphibolite which were probably basic volcanics suggest that a volcanic-exhalative origin is also possible. The thinness of the Koriga iron-formation bands and their geochemical similarity with volcanic-exhalative iron-manganese deposits described from elsewhere (Cyprus Umber: Robertson 1978; Redstone, Ontario: Robinson 1984; Isua: Dymek & Klein 1988) is suggestive of a similar mode of origin.

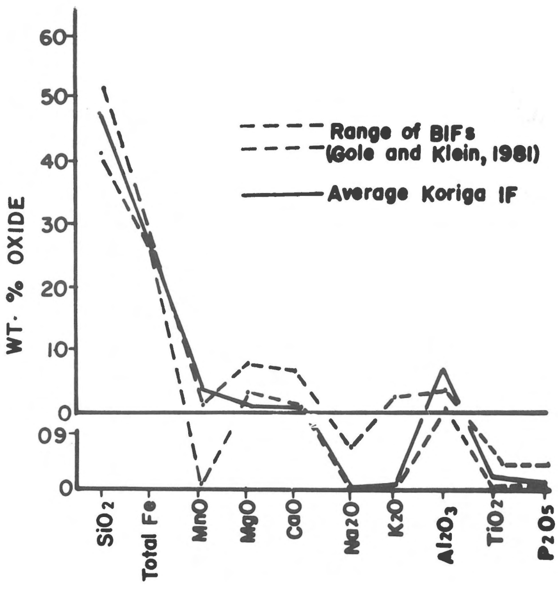

Fig. 5. Average major element composition of Koriga iron-formation compared to the range of average compositions of banded iron-formations given by Gole & Klein (1981).

Table 2. Mineral chemistry

	KO-1		KO-2	
	Grunerite	Garnet	Grunerite	Garnet
SiO_2	48.40	37.06	49.71	36.04
Al_2O_3	0.22	18.16	0.15	18.12
FeO	44.99	31.50	37.20	27.01
MnO	2.32	7.88	2.70	14.49
MgO	2.11	0.36	7.15	0.48
CaO	0.29	5.36	0.44	2.45
H_2O calc.	1.83		1.89	
Total	100.16		98.44	
Oxygens	24 (O,OH)	12	24 (O,OH)	12
Si	7.917	3.032	7.900	3.016
Al	0.042	1.752	0.028	1.787
Fe^{3+}	0.041	0.248	0.072	0.213
Fe^{2+}	6.155	1.908	4.868	1.677
Mn	0.321	0.546	0.364	1.027
Mg	0.514	0.044	1.694	0.060
Ca	0.051	0.470	0.074	0.220
Totals	15.041	8.000	15.000	8.000

The low trace element contents of the Koriga iron-formation is also similar to some trace element-poor Fe-rich hydrothermal deposits such as those of the Galapagos mounds (Corliss et al. 1978). This similarity in trace element as well as major element contents suggests a similar mode of origin. On the balance, therefore, a derivation of Fe and Mn from volcanic or hydrothermal fluids associated with basic volcanics is favoured.

Truswell & Cope (1963), Turner (1983) and Mucke et al. (1989), have reported the occurrence of similar intercalations of iron-formation in the phyllites of the Maru schist belt, about 150 km NW of the Kushaka schist belt. Correlations have been made between the Maru belt and the Kushaka belt on the basis of similarities in the lithological types, degrees of deformation and metamorphism, and isotopic ages (Turner 1983, Fitches et al. 1985). It has been suggested that the deposits of the Kushaka and Maru Schist belts were formed in a common deep-water basin of the failed-rift type in which tholeiitic lavas were also erupted (Turner 1983). Mucke et al. (1989) have suggested a submarine volcanic-exhalative origin for the Maru and other iron formations of north-western Nigeria on the basis of mineralogical evidence and lithological associations.

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