# PRELIMINARY GEOCHEMICAL INVESTIGATION ON BANDED IRON-FORMATIONS FROM SOUTHERN SOMALIA

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## ABSTRACT

A preliminary study on metamorphosed banded iron-formations (BIF) of the Bur area (Southern Somalia) was carried out in order investigate environmental and depositional conditions for their genesis. Samples from three localities (Bur Galan, Bur Daimir and Quadia) were analyzed for main and trace and ultratrace (Ag, Au and Pt-group) elements. Total iron contents (as $Fe_2O_3$) vary between 35.4 and 45.4 % with average contents sensibly lower than previous estimates. The amount of (detrital" elements (Al, Ti, Cr, Na, Ba, etc.) is very low, as are abundance levels of trace siderophile elements (Mn, Zn, Co, Ni, etc.). Two samples from the Bur Daimir outcrop exhibit abnormaloly high Au contents. The Somali BIF seem to be compositionally similar to oxide-rich metamorphosed Precambrian banded formations from various continents, especially to those of Proterozoic age. According to present classification of iron-rich sediments the Somali BIF fit well in the oxide-rich facies of the Lake Superior type (Gross, 1980). Preferred depositional sites could be represented by the so-called MECS environments (metazoan-poor, extensive, chemical-rich shallow sea) defined by Kimberley (1979). Two samples of carbonate rocks associated to the Bur Galan iron-formations were chemically and isotopically studied Their $\delta^{18}O$ values (14.6 and 20.3 % SMOW) are consistent with an origin from marine carbonates of middle-upper Precambrian age. These data seem to reinforce previous hypotheses that the Somali iron-formations were deposited during the Proterozoic.

## RIASSUNTO

Sono state studiate chimicamente alcune formationi ferrifere a bande (BIF) metamorfosate presenti nella zona dei Bur nella Somalia Meridionale. Sono stati analizzati i costituenti principali ed in tracce (compresi alcuni metalli nobili) i campioni provenienti dalle località di Bur Galan, Bur Daimir e Quadia. Il contenuto in ferro totale, espresso come $Fe_2O_3$, varia dal 35.4 al 45.4 %, risultando inferiore rispetto stime precedenti. La quantità di elementi di probabile origine detritica (Al, Ti, Cr, Na, etc.) è molto bassa e così pure quella di elementi siderofili a livello di traccia (Mn, Zn, Co, Ni, etc.). Due campioni dell'affioramento di Bur Daimir presentano contenuti relativamente alti in Au. Per composizione chimica e mineralogica i sedimenti ferriferi della Somalia risultano abbastanza simili a certe formazioni ferrifere metamorfosate di età Precambriana di altri continenti. In accordo con i correnti schemi di classificazione genetica dei BIF, le formazioni ferrifere Somale rientrano nellà facies ricca di ossidi di tipo "Lake Superior". La deposizione del materiale sedimentario estremamente ricco in silice e ferro potrebbe essere avvenuta in un bacino marino poco profondo, caratterizzato da intensi processi di precipitazione chimica per cause non ben definite e dall'assenza quasi totale di apporto detritico. Sono stati analizzati chimicamente ed isotopicamente due campioni di marmo calcitico associato ai BIF di Bur Galan. I valori di $\delta^{18}O$ (14.6 e 20.3 % SMOW) suggeriscono una genesi da carbonati marini di età Precambriana medio-superiore. Questo dato rafforza l'ipotesi che i sedimenti ferriferi Somali siano stati depositati nel Proterozoico.

## INTRODUCTION

The banded iron-formations (BIF), deposits of laminated chert and iron oxides accompanied by variable amounts of silicate and carbonate minerals and sulphides, have greatlyinterested geologists and geochemists, above all in relation to the problem of possible conditions on the earth's surface during the Early Precambrian. Most of these deposits, in fact, are of Archean or Middle-Precambrian age and their unusual properties and distribution in in time and space given rise to



a great deal of controversy regarding the paleoenvironmental conditions of their deposition.

In different area of the crystalline basement of Southern Somalia, the occurrence of metamorphosed banded iron-formations has been known for some time (Stefanini and Paoli,1916; Usono,1952), mainly attraching attention in relation to their economic potentialities. In recent years, several studies have been made regarding general geology and structural and compositional features of the iron-rich metasediments(Marzocchi, 1973; Massoli Novelli, 1980, 1981). We decide to carry out research program on these formations including mineralogical and geochimical studies. The main purpose of these studies will be: i) further knowledge of the compositional features (original material, age, metamorphic history) of the surrounding basement; ii) paleoenvironmental indications regarding the depositional basin .

## NOTES ON THE GENERAL GEOLOGY OF THE BUR AREA IN SOUTHERN SOMALIA

The banded iron-formations investigated here are localized in the Precambrian crystalline basement of southern Somalia in the Bur area, about 200 km from Mogadisho. Here, the basement consists essentially of high-grade metamorphic rocks and of granitic masses elevated as rounded hills (Bur), wel recognizable in the regional morphology. The basement rocks are largely unexposed because of the presence of a thick eluvial cover.

According to regional stratigraphic studies (Ibrahim and Sassi, 1977) the basement in the Bur area is constituted of two Precambrian metamorphosed igneous-sedimentary sequences, i.e. the older Olontole sequence and the younger Dinsor sequence. At present, no age estimates are available on the older basement rocks. Kozerenko (1972) suggested an Archean age for the Olontole sequence and a Proterozoic age for the Dinsor sequence. Some K-Ar determinations on different types of rocks of the area (Borsi, 1955) gave 600-650 m.y. and this age is considered to date the end of the last episode of high-grade metamorphism. A recent total rock Rb-Sr isochronic age (Sighinolfi, unpublished data) for the intrusive Bur Mun granite was 652 ± 12 m.y.

The iron-formations presumably occur in the younger Dinsor sequence in some localities that have been described in detail by some authors dealing with their economic potentialities. The most important deposit is that of Bur Galan where most of the samples here studied have been collected.

## COMPOSITIONAL AND STRUCTURAL FEATURES OF THE BANDED IRON-FORMATIONS

Massoli-Novelli (1980, 1981) and previous researchers have described five main localities in the area comprised between Baidoa and Dinsor in which banded iron-formations are exposed. The outcrops appear to be aligned along a NNW-SSE trend for about 50 km. Each outcrop consists of quartz mesobands alternating with iron-oxide micro-mesobands (hematite and magnetite). The rocks are strongly folded and recrystallized under conditions of high-grade metamorphism. The main banding of the rocks is coincident with the regional NNW-SSE pattern. The dipping of the iron-rich formations in most localities is vertical or subvertical.

According to Massoli-Novelli (1981), the Bur Galan deposit consists of two sub-parallel flanked bodies forming an anticline-like structure bordered by high-grade metamorphic rocks (migmatites) and intrusive granites. Some tens of meters from the southwestern border the country formations contain some layers of whitish - pink marbles formed of large crystals of pure calcite. Neighbouring mining works discovered the presence of metasediments and amphibolite bands in the basement rocks. Thus, it can be concluded that the iron-formations were part of a sedimentary sequence that has been later metamorphosed and disturbed by later intrusions of granitic masses.

Mineralogically, the only Fe-phases present are hematite and magnetite. Magnetite usually is partly transformed in hematite and contains dark-grey coloured thin lamellae of exsolved ilmenite. In addition to Fe-oxides the rocks contain small amounts of chlorite and Fe-rich amphiboles of the series cummingtonite-grunerite rather equally distributed between the quartz mesobands and the Fe-oxide bands.

In the present study, we have selected for analysis samples representative of the more common lithological associations. Thus we have descarded samples with abnormal banding, for example with thickFe-rich bands. At Bur Galan and Bur Daimir the samples were collected trasversally with respect to banding and regional patterns. Two samples of carbonate rocks associated to the Bur Galan iron-formations were collected for chemical and isotopic studies.

## CHEMICAL DATA

Main and trace constituents including some precious metals were determined in the banded iron-formations from Bur Galan (5 samples), Bur Daimir (3 samples) and from a locality near Quadia (one sample).



The data are reported in Table 1 together with the results o the analysis of the samples of carbonate rocks (SH 9: whitish - grey marble; SH 10: pink marble) associated to the Bur Galan iron formations. Averages and ranges of recalculated bulk analyses for the Somali BIF and for Early Precambrian and Proterozoic banded iron-formations from other continents are reported in Table 2. The recalculation of the bulk analyses to 100 % on an $H_2O$-and $CO_2$ -free basis was made in the attempt to neglect the effect of different degrees of metamorphism causing dehydration and decarbonation of the rocks (Gole and Klein, 1981).

The iron-rich rocks of southern Somalia are rather homogeneous in composition when compared to Precambrian iron-formations from most areas. It must be stressed, however, that the data in Table 2 can only be used for general comparisons. Banded iron-formations are in fact very unhomogeneous and the averages and ranges in Table 2 are based on a relatively small number of analyses.

The Somali BIF present relatively low iron contents when compared with other Fe oxide-rich formations. The calculated average total iron (38.7 as $Fe_2O_3$) is also lower than previous estimates (see Massoli-novelli, 1980). Silica, on the contrary, is very high and rather homogeneously distributed between the samples analyzed. The Ca and Mg contents in most samples tend to vary sympathetically (Fig. 1) and show a relatively restricted range (CaO: 0.09-1.27; MgO: 0-2.95 %). As carbonates are Practically absent, both Ca and Mg must be contained in minor silicate phases. As regards elements of possible "detrital" derivation (Al, Ti, Na, K, etc.), their abundance levels are very low when compared with the average composition of other iron-rich sediments. The abundances of these elemnts in the various samples reflect the percentage of silicates like chlorite and amphibole.

The trace element geochemistry of the Somali BIF is characterized by extremely low contents of siderophilic (Ni, Co, V, Zn) and calcophilic (Cu) elements. Also the abundance levels of minor "detrital" elements like Ba, Sr, Ti and Zr are well below the levels found in different facies of iron-rich sediments (see Table 3). As regards the precious metals geochemistry, Pd is practically absent while, surprisingly, the samples from the Bur Daimir rocks present appreciable traces of Au and Ag.

The analysis of the Bur Galan marble samples confirm that they consist almost totally of Ca carbonates with a very small amountsof "detrital" elements. On these samples, a C and O isotopic analysis was

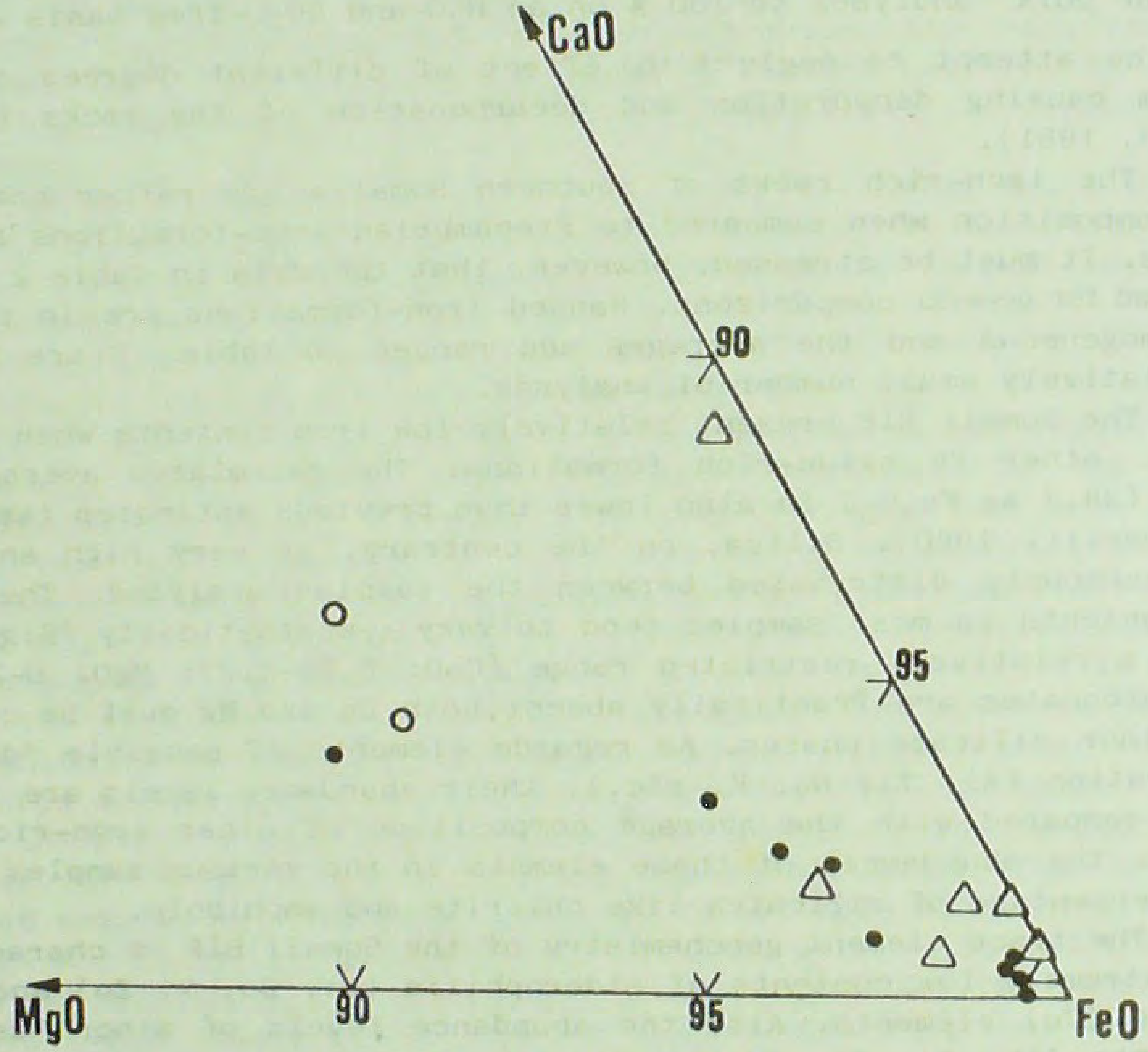


Fig. 1 - Iron (as FeO)-MgO-CaO composition of the Somali iron-formations (solid circle) compared with that of the Australian Marra Mamba formation (open circle); (Klein and Gole, 1981) and with some MECS (mletazoan-poor, extensive, chemical-sediment-rich, shallow-sea) iron-formations (triangle; Kimberley, 1979).



carried out that gave the following results:

| | $\delta^{18}O$(SMOW)% | $\delta^{13}C$(PDB)% |
|---|---|---|
| SH 9 (white marble) | + 14.6 | + 4.1 |
| SH 10 (pink marble) | + 20.33 | + 3.9 |

The carbon isotopic composition of the Bur Galan marbles in rather rich in C-13 when compared with that of modern marine carbonates. Carbonates in Precambrian iron-rich deposits were frequently found very depleted in C-13 and this has been considered by some Authors (Perry and Tan, 1973; Becker and Clayton, 1972) as evidence of organic activity during iron-formation deposition. It should be noted that the Bur Galan marble do not originate from carbonate phases coprecipitated wich silica and iron-oxides but from carbonates deposited in the same sedimentary basin under distinct sedimentary conditions. Post depositional exchange with groundwater during diagenesis (Degens and Epstain, 1962) or other seconda processes may introduce an enrichment in C-13 in carbonates. However, this "age effect" for C isotope chemistry is still debated (see e.g. Veizer and Hoefs, 1976). On the contrary, an "agee effect" is universally accepted for the oxigen isotope ratio of carbonates, the older carbonates becoming progressively depleted in O-18. The $\delta^{18}O$ values of the Bur Galan marbles are well in the range of those of marine carbonates of Precambrian age (see e.g. Schidlowski, 1976; Sighinolfi et al., 1980; Sighinolfi, and Torquato, 1984). Thus the isotopic data tend to suggest a Precambrian age for the sedimentary sequence containing the iron-rich deposits.

## FACIES CLASSIFICATION AND PALEOENVIRONMENTAL IMPLICATION FOR THE SOMALI IRON-FORMATIONS

The limited number of samples analyzed, the overprinting of tectonic and high-grade metamorphic episodes that may have disturbed the original chemical and mineralogical fearures and the lack of suitable indications on the time of deposition of the sedimentary sequence hinder ani unequivocal conclusion about environmental features and depositional processes that originated the iron-rich rock of southern Somalia. The results of this work and other available data allow some tentative interpretations in terms of sedimentary mineral facies and paleoenvironmental conditions.

It has been stressed (e.g. Gole and Klein, 1981) that stratigraphic sequences in which iron-formations occur are highly variable and this indicates that iron-deposits formed in many depositional environments. Several classifications for the iron-formations based on depositional features and chemical composition were proposed. Gross (1965, 1980) distinguishes two main types of iron-formations, i.e. the Algoma and the Lake Superior types, the first containing appreciable amounts of clastic material, the latter constituted essentially of chemical-precipitated silica and iron minerals (oxides, carbonates, sulphides). The Lake Superior-type iron-formations are essentially deposited with quartzite, dolomite and black shales in continental-shelf environments, while the Algoma-type with volcanic and greywacke rock assemblages along volcanic ares, rift zones and deep-seated fault and fracture systems. The differences in the source materials and in depositional mechanism cause differences in main and trace chemistry of the iron-formations, the Algoma-type being much richer in trace metals and "detrital" elements (Gross and McLeod, 1980).

Kimberley (1978, 1979) distinguishes three main depositional environments for iron-formations: a) shallow-volcanic-platform, b) metazoan-poor, extensive, chemical-sediment-rich shallow sea, c) sandy, clayey and oolitic shallow-inland sea. The group b) (MECS) iron-formations must display many analogies with the Lake Superior-type iron-formation. Both these iron deposits originate from pure silica and iron mineral chemically precipitated in shallow-sea environments poor volcanic rocks and sediments of volcanic derivation.

On the basis of the proposed schemes of classification of iron-formation and taking into account the compositional features of the Somali BIF we are induced to classify them into the Lake Superior type. Their most probable depositional environments appear to be those of the MECS iron-formations. The extremely low content of detrital elements and siderophilic metals in the Somali iron-formations suggest that they were deposited in special environments in which silica and iron precipitated selectively. The physico-chemical conditions in these environments as well as the causes of the rhythmic silica-iron mineral deposition are largely unknow and still coontroversial. According to some Authors (Trendall and Blokley, 1970; Kimberley, 1975) a possible setting for chemical-rich banded sediments must have been one of mineral slope over great distances, like the modern Bahaman Andros platform.

If we accept that the present mineral assemblages of the Somali iron-formation essentially reflect primary sedimentary mineral



assemblages, we must conclude that the chemical deposition of silica and iron occurred under conditions of oxide-rich facies. On both empiric and theoretical grounds (Krumbe im and Garrels, 1952; Krauskop, 1967) such a facies is indicative of strong positive Eh conditions in the depositional environment of the iron-rich sediments.

To end, we have to deal with the problem of the age of the Somali iron-formations. Massoli-Novelli (1982) observes that, although most of the BIF are of Archean or Early-Middle Proterozoic age, most of the known African iron-formations seem to be of much younger age. He proposed that in Africa a group of iron-formlations may represent a stratigraphic marker in Proterozoic dating, a peculiar sedimentary episode occuring at least 1.000 m.y. ago.

Studies on Precambrian iron-formations have shown that,although the bulk chemistry of the major formations is largely independent of deposit age, the chemical-sediment-rich types seem to be predominant in the Middle to Late Precambrian 1800-2200 m.y. ago (Kimberley,1979). These considerations and the fact that the isotope chemistry of the Bur Galan marbles fits well into that of Precambrian marine carbonates led us to ptospect a similar age for the Somali iron-formations.

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Table 1. Main and trace constituents in individual samples of iron-formations and associated carbonate rocks from Southern Somalia.

| | SH 4 BIF | SH 5 BIF | SH 6 BIF | SH 7 BIF | SH 8 BIF | SH 9 marble | SH 10 marble | SH 15 BIF | SH 16 BIF | SH 17 BIF | SH 18 BIF |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | BUR GALAN | | | | BUR DAIMIR | | | QUADIA |
| $SiO_2$ | 55.77 | 60.62 | 52.84 | 54.44 | 61.48 | 2.75 | 1.61 | 58.63 | 61.51 | 62.80 | 63.66 |
| $TiO_2$ | 0.02 | 0.03 | 0.15 | 0.02 | 0.03 | 0.05 | 0.05 | 0.01 | 0.02 | 0.02 | 0.02 |
| $Al_2O_3$ | 0.48 | 0.47 | 0.59 | 0.60 | 0.45 | 0.66 | 0.57 | 0.53 | 0.53 | 0.74 | 0.51 |
| $Fe_2O_3$(*) | 42.24 | 34.36 | 44.33 | 42.58 | 35.50 | 1.65 | 1.40 | 40.27 | 37.49 | 35.82 | 35.37 |
| MnO | 0.03 | 0.03 | 0.02 | 0.02 | 0.02 | 0.10 | 0.10 | 0.04 | 0.04 | 0.03 | 0.02 |
| MgO | 0.91 | 2.95 | 0.91 | 1.16 | 1.22 | 0.75 | 0.68 | 0.16 | 0.00 | 0.20 | 0.19 |
| CaO | 0.32 | 1.27 | 0.87 | 0.94 | 1.03 | 93.20 | 94.78 | 0.22 | 0.23 | 0.16 | 0.09 |
| $Na_2O$ | 0.13 | 0.11 | 0.13 | 0.07 | 0.11 | 0.12 | 0.12 | 0.09 | 0.09 | 0.10 | 0.07 |
| $K_2O$ | 0.03 | 0.04 | 0.05 | 0.06 | 0.05 | 0.23 | 0.22 | 0.02 | 0.04 | 0.04 | 0.02 |
| $P_2O_5$ | 0.07 | 0.12 | 0.11 | 0.11 | 0.11 | 0.49 | 0.47 | 0.04 | 0.05 | 0.09 | 0.07 |
| Cr (ppm) | 20 | 36 | 41 | 38 | 37 | 1 | 2 | 19 | 15.5 | 78 | 114 |
| V " | 3.4 | 5.0 | 4.8 | 5.6 | 5.6 | n.d. | n.d. | 4.8 | 2.1 | 2.5 | 11.2 |
| Ni " | 1.1 | 1.5 | 0.9 | 0.9 | 1.6 | 1.7 | 1.3 | 0.7 | 0.8 | 1.1 | 2.6 |
| Co " | 6 | 4 | 7 | 7 | 5 | 4 | 3 | 6 | 7 | 6 | 4 |
| Zn " | 32.1 | 27.3 | 33.3 | 37.7 | 26.1 | 24.9 | 25.3 | 22.0 | 24.9 | 32.9 | 24.1 |
| Rb " | 10 | 10 | 10 | 10 | 10 | 16 | 18 | 10 | 10 | 10 | 10 |
| Sr " | 10 | 10 | 10 | 10 | 10 | 97 | 62 | 10 | 10 | 10 | 10 |
| Ba " | 70 | 121 | 263 | 216 | 298 | 154 | 223 | 65 | 58 | 50 | 85 |
| Zr " | 10.4 | 5.0 | 1.5 | 11.2 | 11.0 | 74 | 57 | 3.3 | 9.0 | 6.1 | 5.6 |
| Pd (ppb) | $<2$ | $<2$ | $<2$ | $<2$ | $<2$ | n.d. | n.d. | n.d. | $<2$ | $<2$ | 2.5 |
| Au " | $<5$ | $<5$ | $<5$ | $<5$ | $<5$ | n.d. | n.d. | n.d. | 45 | 90 | $<5$ |
| Ag " | $<10$ | $<10$ | $<10$ | $<10$ | $<10$ | n.d. | n.d. | n.d. | 10 | 15 | $<10$ |

$CO_2 < 0.1\%$ in all BIF samples; Li $<1$ ppm; Cu $<5$ ppm in all samples;

(*): total iron as $Fe_2O_3$; main constituent data recalculated on $CO_2$- and $H_2O$-free basis.



Table 2. Averages and ranges of the main constituents of the Somali BIF and of iron-formations from other continents.

| | Somali BIF | Algara block (Archean) (1) | Montana (Archean) (1) | Joffre member (Proteroz.) (1) | Labrador Trough (Proteroz.) (1) | Marra Mamba (oxide f.) (2) | Algoma (oxide f.) (3) | Lake Superior (oxide f.) (3) |
|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 59.08<br>52.81-63.76 | 49.07<br>21.5-68.3 | 45.53<br>33.6-59.5 | 43.31<br>7.7-59.1 | 44.33<br>15.2-63.6 | 42.25 | 51.62 | 49.50 |
| $TiO_2$ | 0.035<br>0.01-0.15 | 0.04<br>0.0-0.18 | 0.06<br>0.0-0.18 | 0.07<br>0.01-0.28 | 0.10<br>0.0-0.59 | 0.20 | - | - |
| $Al_2O_3$ | 0.54<br>0.45-0.74 | 0.70<br>0.01-3.51 | 1.80<br>0.01-5.86 | 1.72<br>0.04-7.54 | 0.74<br>0.0-4.23 | 0.40 | 3.06 | 1.45 |
| $Fe_2O_3$ | 38.66 (*)<br>25.37-44.33 (*) | 18.98<br>1.7-37.6 | 26.91<br>3.4-38.3 | 20.16<br>3.1-40.1 | 16.87<br>0.0-77.9 | 22.50 | 27.49 | 37.12 |
| FeO | | 23.65<br>14.4-66.6 | 17.51<br>4.5-27.3 | 22.53<br>14.3-33.6 | 23.68<br>1.1-40.9 | 16.87 | 13.28 | 8.59 |
| MnO | 0.027<br>0.02-0.04 | 0.55<br>0.04-2.76 | 0.64<br>0.01-3.26 | 0.36<br>0.04-2.68 | 1.01<br>0.12-2.66 | 0.12 | - | - |
| MgO | 0.85<br>0.0-2.95 | 3.46<br>1.0-9.53 | 3.82<br>1.25-5.72 | 4.86<br>1.78-14.81 | 6.25<br>0.48-13.66 | 3.78 | 1.56 | 1.30 |
| CaO | 0.57<br>0.22-1.27 | 2.68<br>0.32-7.61 | 3.01<br>0.51-11.48 | 4.97<br>0.05-37.4 | 6.55<br>0.0-22.4 | 5.81 | 1.54 | 1.65 |
| $Na_2O$ | 0.10<br>0.07-0.13 | 0.11<br>0.02-0.57 | 0.34<br>0.01-0.97 | 0.39<br>0.01-2.11 | 0.21<br>0.0-1.49 | 0.43 | 0.316 | 0.125 |
| $K_2O$ | 0.038<br>0.02-0.06 | 0.10<br>0.0-0.61 | 0.07<br>0.01-0.21 | 1.15<br>0.0-2.85 | 0.10<br>0.02-0.54 | 0.15 | 0.59 | 0.146 |
| $P_2O_5$ | 0.065<br>0.04-0.12 | 0.16<br>0.02-0.45 | 0.29<br>0.01-0.55 | 0.25<br>0.1-0.60 | 0.06<br>0.0-0.13 | 0.095 | 0.215 | 0.062 |
| Tot.Fe | 27.03 | 31.65 | 32.43 | 31.61 | 30.21 | 28.85 | 29.38 | 32.63 |

(*): total iron; (1): Gole and Klein (1981); (2): Klein and Gole (1981); (3): Gross and McLeod (1980).

Table 3. Comparative data on trace element contents in the Somali BIF and in different types of Canadian iron-formations (Gross and McLeed, 1980).

| | Somali BIF (range) | Somali BIF (average) | Algoma (all facies) | L.Superior (all facies) | Algoma (oxide facies) | L.Superior (oxide facies) |
|---|---|---|---|---|---|---|
| S (ppm) | 177-250 | 213 | 15300 | 2000 | 2900 | 200 |
| Ba " | 50-298 | 136 | 190 | 160 | 170 | 180 |
| Co " | 4-7 | 5.8 | 41 | 28 | 38 | 27 |
| Cr " | 15-114 | 44.3 | 118 | 112 | 78 | 122 |
| Cu " | <5 | | 149 | 14 | 96 | 10 |
| Mn " | 200-4000 | 270 | 1900 | 4900 | 1400 | 4600 |
| Ni " | 0.7-2.6 | 1.2 | 103 | 37 | 83 | 32 |
| Sr " | <10 | | 116 | 37 | 98 | 42 |
| Ti " | 60-890 | 209 | 1240 | 390 | 860 | 160 |
| V " | 2.1-11.2 | 5.0 | 109 | 42 | 97 | 30 |
| Zn " | 22-38 | 29 | 770 | 40 | 330 | 20 |
| Zr " | 1.5-11.2 | 7.0 | 980 | 81 | 84 | 56 |