

Unidentified hydrothermal mineral occurrences in Northern Somalia – first mineral thermometry study

Borislav K. Kamenov, Paraskev Petrov

Abstract. The Northern Somali region concentrates the main occurrences of metallic mineralizations in the country. Together with the regional mapping the area was a target of the principle reconnaissance and prospecting activities and as a result quite a number of base-metal, auriferous, copper and molybdenum manifestations were registered, amongst them many hydrothermal ones. No published information on this genetic type mineralization is available. For lack of funds and political instability during the last 30 years all these manifestations remained only registered points and nothing had been added to their understanding. At present stage of knowledge they are considered as hypothetical resources although some of them could be turned into proved deposits after proper prospecting. This paper centers to the promising hydrothermal occurrences drawing some regularities in their distribution and mineralogical peculiarities. Several genetic groups and typical ore formations are distinguished. Fluid inclusions in selected quartz crystals from different occurrences were subject of mineral thermometry study and the occurrences were assigned to three temperature stages of crystallization (400-350°C, 340-270°C and 220-100°C). The representative hydrothermal occurrences with measured homogenization temperatures of the fluid inclusions in their quartz crystals are briefly portrayed. The outline given in the paper emphasizes some preliminary conclusions which may be useful as prospecting criteria for further more detailed metallogenetic generalizations for this part of Somalia.

Key words: hydrothermal occurrences, ore formations, mineral thermometry, Pb, Zn, Mo, Cu, Au – metallogeny, Somalia

Address: B.K. Kamenov, P. Petrov – Department of Mineralogy, Petrology and Economic Geology, Faculty of Geology and Geography, Sofia University, 1504 Sofia, Bulgaria; E-mail: b.kamenov@gmail.com

Борислав К. Каменов, Параскев Петров. Неизвестни хидротермални метални проявления от Северна Сомалия – първо минерал-термометрично изследване

Резюме. Районът на Северна Сомалия концентрира главните проявления на металните минерализации в страната. Освен регионалното картиране, тази площ е била обект на основните търсеши и проучвателни дейности и в резултат значителен брой манифестации на олово-цинкови, златоносни, медни и молибденови руди са регистрирани, в това число и на много хидротермални. За този генетичен тип минерализации няма публикувана никаква информация. Всички тези манифестации, поради липса на средства и политическата нестабилност през последните 30 години са останали само регистрирани точки и нищо ново не е било добавено за по-доброто им разбиране. В сегашния етап на знание те се считат за хипотетични ресурси, въпреки че някои от тях биха могли да се превърнат в промишлени находища след подходящото им проучване. Статията е съсредоточена към обещаващите

хидротермални проявявания, очертавайки някои закономерности в разпределението им и в минераложкия им състав. Разграничени са няколко генетични групи и характерни рудни формации. Измерени са температурите на хомогенизация във флуидните включения на избрани кварцови кристали от различни рудни проявявания и са отделени три температурни стадия на минерализация (400-350°C, 340-270°C and 220-100°C). На кратко са описани представителни хидротермални рудо-проявявания, чийто кварцови кристали са изследвани. Схематичното изложение на резултатите подчертава някои предварителни заключения, които биха могли да са полезни като търсещи критерии в по-нататъшните по-детайлни металогенни обобщения за тази част на Сомалия.

Introduction

Looking at the references, concerning Somalian geology and mineral resources one will find that the mineral industry made a small contribution to the country's economy. Somalia produced negligible quantities of gemstones, gypsum, salt and sepiolite during the last ten years. The country also has some deposits of feldspar, iron ore, kaolin, limestone, natural gas, piezo-quartz, silica sands, tantalum, tin and uranium, but they were not developed. Somalia's prolonged civil war halted most exploration for mineral resources. The damaged infrastructure, political instability, intertribal fights, anarchy, and administrative chaos in the country have had considerable unfavourable consequences for the mineral sector. What is most interesting is the fact that there is no mentioning of any base-metal, auriferous, copper or molybdenum hydrothermal occurrences in the published references. Not to say anything about some specific mineralogical examinations on them.

The first author being employed as an adviser for the Somalian Ministry of Mineral and Water Resources between 1974 and 1977 had visited and sampled all known by that time mineral occurrences in the country and had carried out some laboratory works on them. A lot of mineralized manifestations were registered, amongst them many hydrothermal ones. Having in mind that the mineral thermometry is a powerful means to decipher the genetic conditions of the ores, quartz specimens of different mineralizations were then separated and the second author measured the trapped fluid inclusions in them. The civil war not only slowed down the development of

the geological activities in the country but also had suspended them for over thirty years. This gap of significant time made Somalia the unique country in Africa where nothing was added to its geological knowledge. That is why we decided to publish our old data on this genetic type ore mineralizations aiming that they could be a modest contribution to the metallogeny of Somalia. The main goal of the paper is to present some data on the hydrothermal in origin metallic occurrences in Somalia and to arrange them conditionally by their temperature of crystallization, knowing quite well that these data are only preliminary.

Geological background

The Northern Somali Mountainous area (Fig. 1) occupies the southern wing of the Yemen-Aden Arch and constitutes the eastern branch of the East African Orogen (Kröner 1984; Stern 1994; Meert 2003). It is a giant swelling of the Earth crust exposed the products of Precambrian sedimentation, metamorphism and prolonged magmatism. This region concentrates the main occurrences of metallic mineralizations and the principle volume of reconnaissance and prospecting operations (British Geological Survey reports and maps in scale of 1: 125 000, 1952-1962; UNDP projects, 1962-1974) were carried out just there. The Precambrian Basement (Daniels 1965; Warden & Daniels 1972; Merla et al. 1973; D'Amico et al. 1981; Warden & Hörkel 1984; Dal Piaz & Sassi 1986; Kröner et al. 1989; Sassi et al. 1993; Kröner & Sassi, 1996; Kuski et al. 2003) was brought to the contemporary erosion surface by uplifting, complicated by different tectonic movements

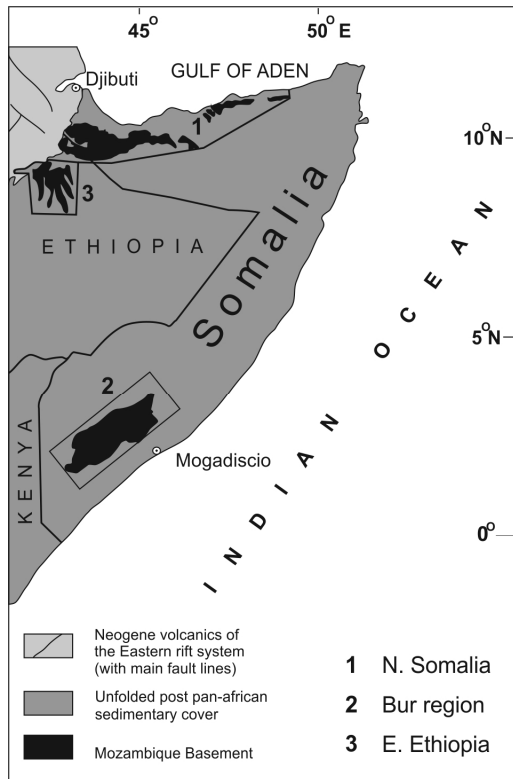


Fig. 1. Geological locality sketch of Somalian main Basement exposures

and igneous processes. The whole block is tilted gently to south and steeper to north. The northern margin of this block is characteristic of many faults from the rift systems of the Red Sea (145°) and of the Gulf of Aden (80°). Intensive tectonic displacements had raised a narrow belt, dismembered by internal dislocations. Various magmatic bodies, granitoids mainly, impregnated the territory in large numbers. The principle structural-metallogenetic units are localized in the uplifted blocks where metamorphic and igneous complexes are exposed. The oldest basement rocks are strongly migmatized ultrametamorphic gneisses peaked in some “hot spots” within the cores of antiforms. In the vicinity of the line Hargeisa-Berbera not only silimanite-bearing facies, but also granulitic

(garnet-and pyroxene bearing gneisses and amphibolites) and on some places even eclogitic ones occur. The supposed age of these remnants of older continental crust is about 1400 Ma (Warden & Hörkel 1984) or 1800 Ma (Kröner et al. 1989). The prevailing part of the North Somali Basement is built up by medium pressure and temperature metasedimentary rocks in the amphibolite facies marked the culminatory folding throughout the Mozambique Orogeny. The wide spread migmatization on them is also typical. The rocks of the Basement influenced by this orogeny are subdivided into several series: (1) the *Gebile metapsammitic series*, (2) the *Borama – Ubali metapelitic series*, and (3) the *Haridad-Mora calcareous series*. The likely time interval of these metamorphosed and folded series is c. 850-750 Ma (Kröner & Sassi, 1996). The upper parts of the basement sequence comprise the (4) *Abdul Qadr series* (c. 700-640 Ma, Sassi et al. 1993) occurred in the margins of the strongly metamorphosed portion of the belt where volcanic rocks (felsic to andesitic rocks, ignimbrites and greenstones) overlie uncomformably the other series. The sequence of these series terminates in the eastern sector of the belt by (5) the *Inda Ad series* consisting of mudstones, siltstones, quartzites, and carbonates. Although folded, the last rocks show only locally evidence of low-grade regional metamorphism in green schist facies. The available radioisotope data, rare finds of organic remnants and correlations indicate that the likely epoch is Middle-Upper Cambrian (750-600 Ma).

Nepheline syenite exposed in the west is referred to the pre-tectonic assemblages. Gabbro, ultrabasic rocks and diorites are interlayered with the garnetiferous gneisses and probably belong to the intertectonic plutonic rocks in the area. Granitoids within the North Somali basement are subdivided to four episodes. The first episode (845-710 Ma, Kröner & Sassi 1996; Teklay et al. 1998) includes the deformed syn orogenic granite-gneisses, metagabbro and syenites and it is related to Mozambique Orogeny. The second

late-kinematic episode covers 750-620 Ma time interval (Kröner & Sassi 1996; Küster & Harms 1998; Teklay et al. 1998). The subsequent third (570-530 Ma, Stern 1994; Lenoir et al. 1994) and fourth episodes (490-450 Ma, Merla et al. 1973; Küster et al. 1990; Kamenov & Lilov, 2012) are related to Pan-African post-tectonic plutonic and deformational events (Kennedy 1964). The wide-spread pegmatite swarms within the west sectors of the basement exposures are assigned to the third episode (560-500 Ma, Kamenov & Lilov, 2012) and could be the final magmatic products of the post-tectonic plutonic activity in Northern Somalia.

Almost all hydrothermal metallic occurrences are confined close to the axes of anticlines and usually fill faults related to Miocene-Quaternary rifting. The largest and deepest fractures were set up still in the Precambrian and after that they had been many times reactivated by the subsequent tectonic movements and by magmatic processes. The most important faults have been most active during the later rifting processes. The vertical displacements along faults of the East African system (N-S to NNE-SSW), Gulf of Aden system (ENE-SSE) and Red Sea system (N-S to NNW-SSE) may be over 1000 m. The relationship between the three systems forms escarpment terrace-like down-thrown sides, generating grabens and horsts.

Hydrothermal metallic mineralizations in Northern Somalia

British geologists as far back in late fifties of the last century registered some single mineralization points during their geological mapping in Northern Somalia (Daniels 1960; Pallister 1959). More metallic occurrences were recorded at the time of the implementation of UNDP projects between 1962 and 1974. The third phase of the UNDP project (1972-1974) especially was engaged to geochemical stream-sediment sampling in Northwestern Somalia and some new findings of such manifestations were added to the list of

hydrothermal records. The start of geological independent activities of the Geological Department with the Somali Ministry of Mineral and Water Resources in 1974 under the guidance of two Bulgarian advisers marked from the very beginning new occurrences and initiated a follow-up metallometry and a preliminary prospecting on some of the most important mineralizations. The number of the records increased and reviews of all known by 1976 hydrothermal occurrences in Somalia appeared (Kamenov 1975, 1976a, 1976b, 1977a, 1977b; Kamenov & Trashliev, 1976). The total number of the registered copper occurrences got to 26, of the lead-zinc ones – to 35, of the molybdenum ones – to 14 and for the gold ones – to 15.

The geochemical prospecting on stream sediments carried out in Northern Somalia (UNDP 1975) resulted of establishment of many positive geochemical anomalies for lead, zinc, copper, and nickel. The allocation of the most important anomalies coincides with some of the areas of the known ore occurrences. The recognizing of the anomaly areas according to the data of the geochemical prospecting was based rather on the determination of areas with high metal contents instead of on the separation of areas of metal contents comparable with the ones of a known ore mineralization, approaching economical scale. The lack of sufficient number primary litho-geochemistry prevents the satisfactory interpretation of the available geochemical data. For instance only 7 anomalies for lead and zinc are directly related to small in scale and quality known base-metal mineralizations. Out of them only Gallo Ado and Golujeit seem to be promising, but they were not prospected properly and therefore the significance of the revealed anomaly was uncertain. In spite of that, it is quite clear that the associations Pb-Zn-Cu of high metal contents are present in Northern Somalia Basement. The number and the significance of such “anomalies” may be disputable, as well as the way of their interpretation, but one thing is beyond any dispute – this is the fact that the revealed anomalies reflect an essential

peculiarity of the metallogeny of the area and that they could be thought as favourable indications for the general assessment of the prospects for metallic ores in Somalia.

It is important to be emphasized that no industrial proved deposit for lead, zinc, copper, molybdenum and gold at the present stage of knowledge in the Somali Democratic Republic is explored. All described occurrences could be classified as hypothetical resources and some of them are surmised to turn probably into deposits on the basis of broad geological knowledge. The only workable tin deposits are known in the area of Madjayan-Dalan (Vladov et al. 1974) but they were not mined at all.

From practical point of view we have subdivided the hydrothermal occurrences in Somalia into several genetic groups, each one comprising various ore metallic formations.

I. Occurrences located within plutonic bodies (Quartz-molybdenite-chalcopyrite formation - example: Darkainle).

II. Occurrences in effusive rocks as small lens-like morphology or ramificated veinlets within metarhyolites and metadacites (Quartz-pyrite-sphalerite-chalcopyrite formation - examples: Abdel Quadr and North Darkainle).

III. Occurrences accommodated in pegmatites and in granite-porphry dykes - (Quartz-molybdenite and quartz-galena-chalcopyrite-pyrite formations - examples: Wai-Wai, Hed Valley, Dobo, Dobo Yer, and Yubare).

IV. Occurrences emplaced in contact-metasomatic replacements (Quartz-sphalerite-chalcopyrite-barite-ankerite-calcite-gold and Quartz-pyrite-chalcopyrite-molybdenite-galena-hematite formations - examples: Galo Ado; Daaremo, Isha Obasha, and Tobsi-west).

V. Telethermal occurrences confined as nests in limestones (Galena-barite formation - examples: Al Miskat, Arorgob, Abasa, and Golujeit).

VI. Occurrences in shear zones, strongly tectonized quartzites, fault zones (Quartz-pyrite formation - example: Bur Mado).

VII. Vein-like occurrences: (Quartz-molybdenite-galena-chalcopyrite-pyrite-arsenopyrite-fluorite with bismuthinite

formation - examples: Sigib, Buhl, Bown, Lejeli, Lodjerti, Dananjieh, Gobed Hulul, Ardahh, Fulanful, Wiget, Bihendula); (Barite-galena formation - examples: Dalan-North, Karin Kul, Unkah, Gedad, Kul, Gedalaan, Velya tug); (Quartz-barite-galena-carbonate-limonite formation - examples: Xidit, Haaji); (Quartz-barite-galena and Quartz-cassiterite formation - example: Dalan, Eruduwe, Shaftaaak); (Quartz-auriferous with pyrite and arsenopyrite formation - examples: Biyo Asse and Debis); (Quartz-pyrite-sphalerite-chalcopyrite formation - example: Arapsiyu); (Quartz-pyrite-chalcopyrite-molybdenite-galena-hematite formation - example: Daaremo).

Generalizing we can enumerate the following hydrothermal metallic ore formations typical for the Northern Somalia: 1. Quartz-molybdenite-chalcopyrite; 2. Quartz-sulphide; 3. Quartz-molybdenite-galena-chalcopyrite-pyrite-arsenopyrite-fluorite with bismuthinite; 4. Quartz-barite-galena-limonite-carbonate; 5. Galena-barite; 6. Quartz-cassiterite; 7. Quartz-auriferous with pyrite and arsenopyrite; and 8. Quartz-pyrite.

Typical geochemical peculiarity in the regional distribution of the hydrothermal occurrences is that always $Zn > Pb$ in the western blocks of Northern Basement, while in the eastern sectors quite the contrary relations are established - $Pb > Zn$. The metal contents are low to moderate. Cu, Ag and Au are the usual trace components in the ores.

The detailed description of all hydrothermal metallic manifestations in Northern Somalia is out of scope of the present paper, but the sampled representative occurrences with estimated homogenization temperatures of the fluid inclusions in their quartz crystals (Table 1, Fig. 2) are briefly portrayed below.

1. Dalan Central occurrence comprises about 1200 cassiterite-containing pegmatite and quartz veins. It is situated near to the crest of the Dalan anticline. The richest quartz veins are E-W trending closely spaced, with average thickness of 2.00 m. and sometimes they are well-arranged in swarms. The average grade is

Sn = 0.178 % and the calculated proved reserves are 2530 tons of tin dispersed in the rock mass (Vladov et al. 1974). Cassiterite, rutile and apatite, together with hematite, muscovite and rare feldspars occur in the central zones of the veins. Pyrite, tourmaline, epidote, braunite, psilomelane, pyrolusite are much less common. Cassiterite in blocks of up to 10-15 cm is concentrated within quartz lenses.

1b. Dalan North occurrence is a lead-barite mineralization located 3 km NNE away from the tin deposit Dalan. The mineralization occurs along the contact of Inda Ad Series with Mesozoic-Neozoic sediments. The area was mapped in scales of 1: 50 000 and 1: 10 000, subjected of metallometric sampling and prospected by trenches and pits. Channel sampling along the tectonized Northern Contact between the Inda Ad Series and Mesozoic sequences and along some faults was carried out. Galena-barite mineralization is closely related to several first-order fault structures. The galena-bearing veins are located within the metamorphic rocks of Inda Ad Series and at the same time in the Jurassic limestones. The close spaced parallel galena-bearing veins are emplaced within the ore-zone, which could be traced about 1 km. Usually short barite veins with irregularly distributed galena crystals ramify out in different directions. The main ore mineral is galena occurred in nests, pods, stringers. Anglesite, cerussite, pyrite, hematite and small grains of electrum are the minor ore minerals. The dominant gangue mineral is barite filled 80-90% of the vein mass. The barite veins with a visible mineralization show lead contents of up to 3-4 per cent, but as a whole the Pb concentration is low. The average assays for Zn are 0.1-0.3%, reaching up to 0.82%. The barium contents range 0.1 to 0.3% outside of the veins and their contents in the channel samples are average 25-30% with maximum peaks of up to 48. Increased concentrations of Pb, Zn, Mo, Ni and Co are revealed by the metallometry along the so-called Northern Ore Fault. The age of the mineralization is Late

Cretaceous "galena" crystals show 110 Ma (Greenwood 1960). Some of the manifestations could have been redeposited in the younger and rejuvenated faults. At the current stage of investigation, the occurrence shows too low contents of ore components but there are enough reasons the manifestation to be recommended for possible further investigations.

2. Xidiq occurrence is situated in eastern sector of North Somalian basement near to the Escarpment. The mineralized 6 subparallel quartz veins are emplaced entirely within the metasediments of Inda Ad Series. The strike of galena-bearing veins is 20 to 60°N with variable thickness and they were traced out with interruptions to 1 km. The occurrence is in the area of intersection of two faults. The older one (150°N) is displaced (350-400 m) with a pronounced left side strike slip component by the younger fault (290°N).

The prevailing mineral in the veins is quartz. Isolated nests of galena are dispersed and usually the single individual crystals have size of up to 1 cm while the crystal aggregates are larger up to 5 cm. Galena crystals and aggregates are covered with anglesite coating. Close to the quartz-galena veins a zone of carbonate-limonite brecciated material is noted. Short and thin quartz veinlets, containing incidental galena mineralization are observed not very far from the site of the occurrence. The insignificant mineralized sectors in the veins and their extremely sporadic distribution are the reason the occurrence to be considered without any practical importance from economical point of view.

3. Arapsiyo occurrence is one of the many copper manifestations revealed in the area Gebile-Hargeisa. Small quartz veins (traced out several hundred meters) occur in quartzites and micaceous schists, amphibolites and granite-gneisses. Chalcopyrite, sphalerite, galena and pyrite are unevenly distributed in insignificant quantities within the veins. Copper grades in separate samples are 0.20 to 0.95%. One of the regional geochemical anomalies coincides with the area of distribution of quartz-sulphide veins. The

Table 1. Homogenization temperatures of quartz crystals from representative ore formations of the hydrothermal metallic occurrences in Northern Somalia

No	Sample	Occurrence	Co-ordinates	Ore formation	T°C Homog.
1	107-D75/BK	Dalan-Central, vein 56	11°05' N, 48°50' E	Quartz-cassiterite	360-380
1b	110/BK	Dalan-North	11°06' N, 48°50' E	Barite-galena	160-190
2	13/BK	Hidiq (Idiq)	11°02' N, 48°46' E	Quartz-barite-galena-carbonate-limonite	270-340
3	358/BK	Arapsiyo	9°40' N, 43°50' E	Quartz-pyrite-sphalerite-chalcopyrite	350-370
4	I/BK 354/BK	Biyo Ase	9°50' N, 43°55' E	Quartz-auriferous-with pyrite and arsenopyrite	350-400
5	I/BK 354/BK	Biyo Ase	9°50' N, 43°55' E	Quartz-auriferous-with pyrite and arsenopyrite	150-160
6	361/BK	Daaremo	9°48' N, 43°35' E	Quartz-pyrite-chalcopyrite-molybdenite-galena-hematite	360-380 150-200
7	372/BK	Sigib ridge	10°17' N, 43°45' E	Quartz-molybdenite-galena-chalcopyrite-pyrite-arsenopyrite-fluorite	160-200
8	5a/BK	Buhl	9°49' N, 43°56' E	Quartz-molybdenite-galena-chalcopyrite-pyrite-arsenopyrite-fluorite	180-220
9	389/BK	Debis	9°49' N, 44°50' E	Quartz-auriferous-with pyrite and arsenopyrite	300, near to surface; gas
10	326/BK	Hed Valley	9°55' N, 44°43' E	Quartz-molybdenite; Quartz-galena-chalcopyrite-pyrite	350-370 170-200
11	12/BK	Bur Mado	10°14' N, 43°43' E	Quartz-pyrite	core 370, rim 215 P 1000-1100 atm H 3.5-4.0 km
11b	10/BK	Wai-Wai	10°12' N, 43°40' E	Quartz-galena-chalcopyrite-pyrite	160-200
12	344/BK	Galo Ado	9°44' N, 43°52' E	Quartz-pyrite-chalcopyrite-molybdenite-galena-hematite	400 100-200
13	63/BK	Karin Kul	11°08' N, 48°29' E	Galena-barite	150-180

Note: Laferug specimen of comb-like quartz – 195°C. The numbers of the occurrences correspond to the sketch in Fig. 1 and to the text

occurrence can be considered only as a positive sign in other reconnaissance works at the present insufficient stage of knowledge.

4 and 5. *Biyo Ase occurrence* comprises 4 gold-bearing quartz veins confined within a

calc-silicate metamorphic succession of Precambrian age. The presence of gold was proved chemically in the cross-cutting quartz veins. The mineralized area is located in the southern flank of an anticline structure and it is

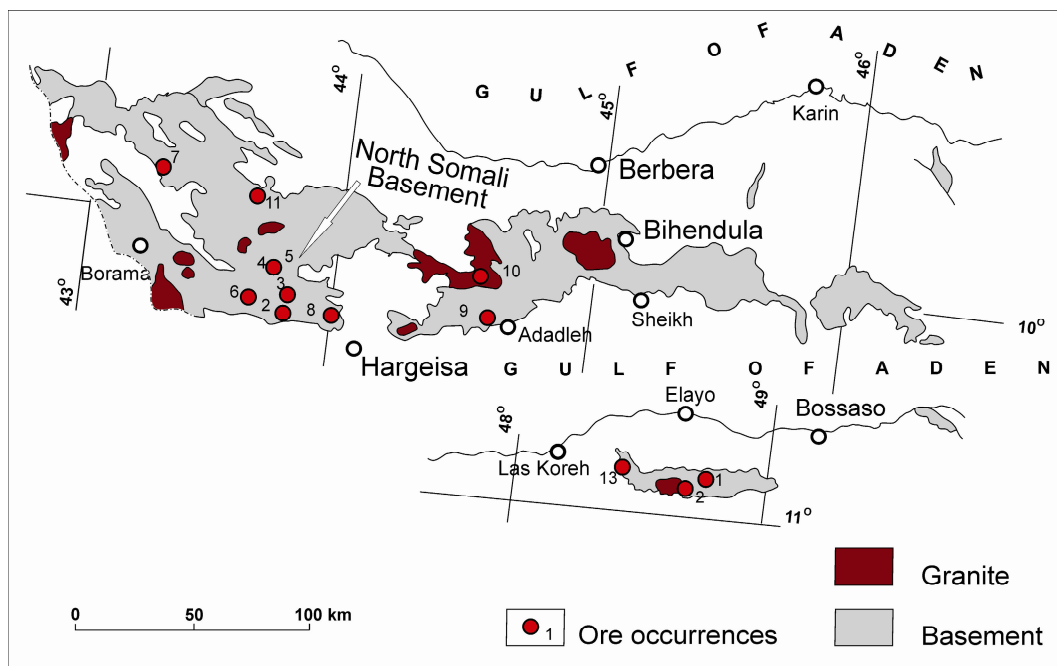


Fig. 2. Map showing the distribution of sampled for quartz mineral thermometry hydrothermal metallic occurrences in Northern Somali Basement. The numbers of the mineralizations correspond to the text and to table 1

in close neighbourhood with the western margin of the folded and elongated massif of porphyry granite, named Dagah Kureh. The veins have been traced by trenches across strike (NNE) in distances of 6 to 20 m. Boreholes cut the veins at depth of 25 m. The mineralization is scarce and it is expressed in form of separate pyrite and arsenopyrite crystals, leaked in the surface. Chalcopyrite and covellite are observed rarely. Iron hydroxides occurred along the faces of the fissures. Collected grab samples have showed traces of gold. The highest results were between 9 and 23 ppm gold and 5-38 ppm silver. Re-sampling of the veins some later on gave a bit poorer results, but still interesting. The sampling of the contact between the ultrabasic Udan Massif and an aplitic vein gave an assay of 11 ppm gold. Traces of gold are found also in the gabbro massif, accompanied by all over the area pyritization, southwards of

the granite massif Dagah Kureh in a cross cutting transversal quartz vein, near to the northern contact of the ultrabasic massif. The existence of mineralized quartz-auriferous veins has been demonstrated, but these single grab samples are quite insufficient to complete the idea of the real practical significance of the occurrence. Many other quartz veins occur in the area, but only a few of them are sampled for gold.

In spite of the fact, that preliminary assays are encouraging enough, the structural picture indicates that these bodies might not be really important, because of their small size and number. It should be emphasized that the near-surface samples would be of little use for assessment, because of wide-spread of leaching. The occurrence Biyo Ase is too small to warrant the hopes for independent profitable mining in the nearest future. Without new finds

of quartz-auriferous veins the gold prospects would not be cleared up. The general picture of the gold potential of whole area could be discussed provided that all quartz veins, including the ones within the metagabbro in the Agamso Tug had been sampled properly.

6. *Daaremo occurrence* includes about 60 quartz veins emplaced in metamorphic rocks referred to the Lower Proterozoic sequence. The veins are accommodated in two systems in relation to the strike orientation of the country rocks: conformable and transversal. The mineralized area is the crest of a major anticline plunging to west and just there a major sub-latitudinal fault zone named Arapsiyo Fault Zone passes. Chalcopyrite is disseminated in very small quantities in the quartz veins, along with galena, pyrite, molybdenite, and specularite. The occurrence is not prospected and for the time being is of academic interest only.

7. *Sigib occurrence* comprises over 40 quartz veins, as well as numerous small quartz veinlets and streaks containing visible molybdenite flakes. Molybdenite forms fine-dispersed impregnations in the mass of the veined quartz. The contact zones of the quartz veins show a higher content of molybdenite, though in the thin veins its segregates are larger. The veins contain also galena, chalcopyrite, arsenopyrite and powellite. Sometimes fluorite is observed as a gangue mineral. The near-to-the vein alterations are in the brecciated zones and they are displayed by beresitization and silification. The area of spread of molybdenite mineralization forms an elongated strip, vast for 10 km and long for about 20 km. This area is within an anticline with NW strike of its axis and undulated hinge. All mineralized veins are concentrated only within the Lower Proterozoic Series. Gneiss-granites, gabbro, dykes of pegmatoid leucocratic granites and pegmatite veins intrude the metamorphic sequence. Two groups of faults occur: (i) NW-SE zones of shearing and crushing and (ii) N-NE zones of brecciation, silification, and beresitization. The quartz veins fill both of these fault directions but only the

quartz veins of sub-meridional strike are molybdenite bearing. The locality where quartz veins are mostly concentrated is singled out under the name of the "Sigib First Zone". This zone is traced along the strike (30°N). The extension of the veins is from 50 to 120 m; thickness – 0.3-1.2 m; strike – 20°-30°. The molybdenite segregations are dispersed irregularly. The molybdenite ochres are frequent. No dissemination of molybdenite in the country rocks is observed.

About 17 lump samples have been collected. Some samples from the country rocks have been taken too. The results are: Mo – 0.02 to 0.25% up to 1.0% in one sample only. Out of the prospected preliminary Sigib I-st Zone molybdenite-bearing quartz veins were found in several other places. Some of the veins contain considerably amount of sulphides (up to 10%), including apart from molybdenite also chalcopyrite, and pyrite.

Although poor in accessibility and water supply, yet the area is a promising province for general survey for molybdenum and accompanying components. It is strongly recommended for setting up specialized geological-prospecting works with the hope that an economic profitable deposit would be estimated.

8. *Buhl occurrence* was discovered by British geologists and prospected preliminary by shallow pits and some trenches. The occurrence was described also by Russian and Chinese prospectors. The molybdenite mineralization is present between an anticline with an E-W axial direction south of the settlement Buhl and a syncline structure. The main structural feature is the intrusion of a large syenite sill (over 1 km wide, traced out for about 25 km), intruded between biotite schists and a metasedimentary series composed largely by impure sandstones. Minor granite, metagabbro and quartz-syenite bodies occur too. Over 90 mineral-bearing veins of various sizes were injected along the marginal hanging wall of the sill. The quartz veins stretch NE-SW in general and N-S occasionally. Some of them measure as much as 200-800 m long and 1-4 m in thickness. Laminated molybdenite and

black bismuthinite are the predominant metallic minerals in the area, while galena is secondary in importance. The schistose crystals of molybdenite display a yellowish-green appearance after oxidation (powellite?). The gangue minerals comprise mainly white quartz and secondary feldspar and muscovite. Molybdenite is found also in some of the pegmatite veins in the area.

The largest quartz vein is followed out by pitting for 150 m, the strike is 70°N, dipping to the NW at 70-85°. This vein is traced out by subsurface workings down to 20 m. The assay results have been discouraging: Bi – 0.4 to 0.6%, Mo – 0.09 to 0.90%, Pb – 0.09 to 0.16%. 16 serial chip-samples from different veins have been analyzed in Beijing in 1972. The results show Mo contents ranging between 0.001% and 0.85%; Bi – 0.001 and 0.236%; Pb – 0.03 and 0.92%; Au – less than 0.2 ppm; Ag – 4.5 to 3.90 ppm; Cu – 0.001 to 0.003%; and Zn – less than 100 ppm. Molybdenum-richer veins are poor in bismuth contents or vice versa. In the largest outcrop the bismuthinite is predominant. North and south of this area other ore bodies occur with molybdenite predominantly present. The quartz veins have a relatively high content of silver. The occurrence in itself is too small to be of economic significance. The geological ore reserves preliminary estimated from 13 molybdenum and bismuth-bearing quartz veins respectively with a thickness of over 1 m are about 300 000 tons ore. These veins average 0.294% of molybdenum and 0.41% of bismuth. The further exploration should be advisable only if proper channel sampling continues to show a combined metal content of approximately 1 per cent or more.

9. *Debis occurrence.* Located in Adadleh area, the occurrence is registered by geologists of UNDP without any other information for it. Quartz-auriferous-pyrite poor mineralization is only registered and no prospecting operations were carried out on it.

10. *Hed Valley occurrence* comprises very poor and dispersed molybdenite mineralization in pegmatites, accompanied

with rare crystals of galena, chalcopyrite and pyrite. No prospecting operations were carried out on it, but hardly would it turn into profitable deposit some time.

11. *Bur Mado occurrence* is encountered in the area of Bur Mado Ridge in Northwestern Somalia. Molybdenite-bearing quartz veins with sporadic galena crystals were sampled by semi-quantitative spectral analysis on the lump samples. The results were unsatisfactory: 0.03% of molybdenum; 0.05% of lead and traces of bismuth. Rutile and pyrite were also recognized. The assays of individual chip-samples up to 0.03% of Mo; 0.345 of Bi; 0.04% of Pb and 11 ppm of Ag were reported. The occurrence could be considered only as an indication for the presence of molybdenite mineralization, because of the low grade of the ore.

11b. *Wai-Wai occurrence.* The galena-chalcopyrite-pyrite mineralization is related spatially to hydrothermal alterations on the pegmatites of the piezo-quartz deposit Wai-Wai in the ridge Bur Mado in Northwestern Somalia. The country rocks are represented by ferruginous quartzites with disseminated sulphides, grading 0.4 per cent of copper. The hydrothermal alteration of the pegmatites is expressed by albitization on the feldspars, development of hydromica and forming of cavities in the crystals. The scale of mineralization is negligible and the occurrence hardly could be referred to the promising ones. The estimation of the occurrence, based on the very limited geological information appears to be negative. The manifestation may be evaluated only as a mineralization point of no direct economic interest. Nevertheless the question of the final assessment will be open until a specialized work is set there.

12. *Galo Ado occurrence* contains 8 mineralized veins consisting of sphalerite, chalcopyrite, galena and barite. The gangue minerals are quartz, carbonate, dolomite, ankerite, chlorite, serpentine, and scapolite. The secondary ore minerals are malachite, azurite, bornite, chalcocite, smithsonite and tenorite. Iron- and manganese hydroxides are well present. The wall rocks include a calc-

silicate Precambrian sequence. The granitoid massif Dagah Kureh occurs in close neighbourhood with the mineralization. Metamorphic rocks build up the southern limb of a great anticline and the vein area is near to its axial crest. The mineralogy of the veins bears a resemblance of skarn association. All "veins" are conformable with the strike and dip of the country rocks. A cursory schematic mapping on 40 km² area in scale of 1:32 000 has been carried out, as well as a detailed sketch for distribution of the metalliferous veins in scale of 1: 1000. Soil sedimentary geochemistry prospecting in scale of 1: 5 000 within the area of 1.2 km² revealed three isometric anomalies for zinc almost coinciding with the site of the metalliferous veins. Selected sections have been subjected of excavating works.

Two stages of mineralization can be recognized: mainly sphalerite-galena-chalcocopyrite association included into serpentine, ankerite or chlorite matrix represents the older one. The later stage is composed of galena-quartz veins crosscutting the minerals of the first stage. The ore mineralization of the first stage is of importance for the assessment of the whole deposit. The mineralization was traced along the length of the veins between 5 and 160 m.

The assays of single chip-samples from the vein material demonstrate values to 1% copper and 5.5% zinc for the western sector of the occurrence, but only for very limited sections. 22 out of 57 samples show traces of gold (amongst them 3 samples with 2.9 and 10 ppm Au). The majority of the samples showing gold contents contain up to 35 ppm silver. We could state that the volume and the quality of the familiar metalliferous bodies are obviously out of any economical proportions at the current economical conditions, even if these bodies would have been mineralized without interruption. Without a careful search for discovering new ore bodies and occurrences of this type in the area, every conclusion should be unreliable until the final clearing up of the morphology in depth and the grade of the ores.

The idea about the negligible scale of the occurrence could be changed entirely if the economic concentration of the precious metals Au and Ag was confirmed properly.

13. *Karin Kul occurrence* is located in Northeastern Somalia in the periclinal part of an anticline, complicated by secondary folds. About 40 barite veins with galena are exposed not very far from the Northern Tectonized Contact of the Inda Ad Series. All veins are located within Inda Ad Series and they are related to the main fault structures of the area. Three systems sulphide- and barite- bearing zones can be noted. The first system is composed of veins almost N-S trending. These veins are intensively stained by iron oxides. They contain sporadic galena crystals. The veins of the second system are short and they do not bear galena. They trend in north-east direction and cut the veins of the first system. The third system consists of veins having almost NW strike. They are split off of the main Tectonized Contact Zone or in most cases they are parallel to it. Most of the veins in this system are barite-carrying together with sulphides, but in some places they can be represented as barren quartz veins. The veins are traceable in strike from 20 to 250 m. Usually the veins can be found in a band about 800 m in length, located almost parallel to the Contact Zone. Galena crystals occur in the barite veins as irregular impregnations, nests, accumulations and stringers. The richest ores are found in the places where the vein changes its strike or dip. The selvages of the veins are the preferred places for concentration of the galena crystals. Two generations galena can be separated. Galena^I impregnates barite mass and galena^{II} is in the quartz stringers intersecting the barite veins. Irregular, fine-grained impregnations of native silver and gold flakes sized less than 0.01 mm in diameter are noted. The following minor minerals in small quantity can be observed in the veins: cerussite, anglesite, carbonate, quartz, barite, iron hydroxides etc. The barite is the major constituent of the veins (50 to 90%). The galena distribution is too irregular and large

sectors of the veins very often are practically barren. The veins terminate when they reach the Jurassic sediments.

The following volume of prospecting activities undertaken by a Bulgarian mapping team was carried out: 6 km² mapping in scale of 1: 10 000, metallometry (lithogeochemical sampling), sampling for mineralogical X-ray diagnostics and for other purposes. The lead concentration in the veins varies from less than 0.1% to over 1.0%. The zinc concentrations range 0.02-0.3% and usually they are correlated well to these of the lead. Only 5 specimens with higher lead and zinc contents show increased copper concentrations – 0.01% and only in one sample this concentration is getting to over 0.3%. The spectrally determined concentrations on the monomineral concentrates of galena show silver content of over 200 ppm. The metals arsenic and antimony, even in insignificant quantities appear in the most western part of the area. The order of their concentrations is normally between 0.006 and 0.03, if not about 0.6%. Ni analyses show to 0.01-0.03% and it is accompanied always by low, but permanently conjugated with it Co quantity.

The probable geological age of the base-metal mineralization is likely to be post-Jurassic to Tertiary. The metal contents are relatively poor, the occurrence needs a systematic prospecting and more qualitative chemical control, but the discovering of native gold and native silver in the galena deserves prospecting in more details.

Homogenization temperatures

The measured homogenization temperatures of all selected quartz crystals from different hydrothermal occurrences cover the span of 400 to 100°C and fall entirely in the range of the hydrothermal stage of mineralization. Three temperature substages could be outlined: Ist high-temperature (350-400°C); IInd medium-temperature one (270-340°C) and IIIrd low temperature one (100-220°C). The high-temperature substage comprises metallic

manifestations containing quartz-cassiterite, quartz-molybdenite, quartz-sulphide and quartz-auriferous ore formations. The medium-temperature substage includes quartz-barite-galena and quartz-auriferous ore formations. The low-temperature substage is characteristic for the manifestations with galena-barite, quartz-auriferous and quartz-sulphide ore formations. Two-generation quartz crystallization in occurrences from these formations was established in the quartz-auriferous, quartz-molybdenite, quartz-pyrite-chalcopyrite-molybdenite-galena-hematite and quartz-pyrite ore formations. The first generation shows high temperatures 350-400°C, while the second one completes it in the rims of the large crystals at temperatures 100-220°C. The high-temperature mineralizations are found in the following ore manifestations: Dalan-Central, Arapsiyo, Biyo Ase, Daaremo, Hed Valley, Bur Mado, and Galo Ado. Medium-temperature mineralization is observed in Hidiq and Debis, while low-temperature crystallization is noted in Dalan-North, Biyo Ase, Daaremo, Sigib ridge, Buhl, Hed Valley, Wai-Wai, Galo Ado and Karin-Kul.

Practical corollaries

There have been many speculations as to the source of the metallic hydrothermal mineralizations and as to the geological age of the occurrences. Some geologists think the young rift-forming process as responsible for the mineralization, whereas others support the idea of their origin from earlier ages – Jurassic, Paleozoic or even Precambrian. Most of these views are hypothetical and not well grounded. Contemporary precise dating of the ore minerals is not accomplished and that is why all opinions are unsupported sufficiently. What is obvious is that some regularity in the distribution of the mineralized sites can be outlined and from practical point of view it may be useful for the future prospecting activities. Even we do not deal with deposits, but with single mineral manifestations, it is clear that they are observed only within certain zones related to the principle regional

structures, magmatic bodies or stratigraphical layers. The following points would be significant as preliminary prospecting criteria for the area of Northern Somalia.

1. All molybdenum-bearing occurrences are concentrated within the most northern part of the western sector of North Somali Basement shaping a belt-like molybdenum ferrous zone which can be considered as a potential ore province. All base metal and copper occurrences are distributed southward of this zone and form another metallogenic belt-like polymetallic zone in the western Northern Somalia. The eastern sector of North Somali Basement includes mainly galena-barite occurrences. Coming out of the distribution of the copper occurrences a general trend of decreasing copper prospects eastwards can be noted.

2. A sinistral strike-slip tear up displacement of the "Polymetallic belt zone" along the major fault zone passing between the towns Hargeisa and Berbera is well visualized by the distribution of the occurrences and geochemical anomalies of first priority. The well defined outlines of this zone would direct the future reconnaissance and ore prospecting operations. On the west of this displacement Zn contents always predominates over Pb in almost all metallic occurrences, while on the east quite the contrary - Pb contents prevail over Zn ones.

3. Large intrusive granitic bodies near to the domes of the anticline structures, particularly in the Bur Mado, Daarburuq and Laferug localities are in close vicinity to the molybdenite occurrences. Intermediate to acid intrusive rocks occur in close neighbourhood with most of the ore occurrences. The fields of molybdenum mineralization tend also toward separate intrusive masses such as syenite plutons. The lateral relationship of these syenite massifs with the basic intrusives suggests the idea of the role of hybridization processes between acid and basic magmas as responsible in producing the syenite plutons and copper-molybdenite-bismuthinite manifestations as well.

4. All molybdenum-bearing occurrences

and most of the lead-zinc and copper ones lie within the Lower Proterozoic Basement Series. A close spatial relationship between pegmatite dykes and the ore-bodies in the great majority of the fields of molybdenum mineralization is established. The major part of the pegmatites, pegmatoid granites and granite porphyry dykes are also concentrated in the Lower Proterozoic Sequence.

5. The country rock alterations are usually quite narrow.

6. All molybdenum and most of the polymetallic occurrences are localized in the near-to-the axial areas of the great anticline structures and usually they are arranged along their strike. The junction zones of synclines and anticlines also emplace some of the molybdenum occurrences. The copper manifestations are mostly accommodated in the synclines of the metamorphites of the Lower Precambrian and close to basic intrusions.

7. Several inferred deep-seated fault zones of the so-called "*Somali trend*" (270° to 320°) probably are ore-controlling factors. The Bur Mado deep-seated zone is of special significance for the western part of the basement and it appears to be a trend of high permeability of the Earth crust. Almost all large basic igneous masses for this block are aligned along this trend and in the immediately vicinity to it. Even the good deal of the younger basaltic eruptions is subordinated to this trend, which proves the long life of the zone. Quite a lot of the known metallic mineralizations are in close space relationship to this tectonic zone. The greater parts of the lead-zinc occurrences are situated at fault intersect junctions. The galena-barite manifestations occur mostly in the eastern sector of Northern Somali Basement within Inda Ad Series usually close to border contact zones with the exposures of Jurassic sediments. The faults and crushing shear-zones of submeridional direction (340° to 20° N) filled by quartz veins are accompanied by zones of hydrothermal alteration of the country rocks. The role of this system faults is much essential since they control also the orientation of the

molybdenite-bearing quartz veins. The secondary transverse deep-seated fault zones with apparently sinistral strike-slip movements play great role not only for the tectogenesis, but for the metallogenesis too. They are important trends governing the redistribution of the ore fields. The places of intersection of these transverse zones with the “Somali Trend” deep-seated zones, we believe, have been of importance for the metallic prospects. The post-ore tectonic movements have been widespread and influenced the size of the ore bodies or zones.

8. The ore manifestations had been investigated on the surface outcrops or at insignificant depth. Only part of them had been sampled on very rare grid or with single lump grab samples. No channel samples were taken from them thus the chemical composition was inaccurately assessed. The lead contents are very low in the oxidation zone and without tracing down the veins in depth their economic evaluation will be risky.

9. Geochemical stream-sediment survey carried out in the Northern Provinces indicated a geochemical pattern that is to be related except to bedrock composition also to some metallic mineralizations. The general sequence of the decreasing values for copper with respect to the bedrock type is basalts of Aden rift complex - gabbro, amphibolites and hornblende schists – metavolcanic rocks of Abdel Quadr series - granitoids and metasedimentary Precambrian rocks – Inda Ad rocks series. This sequence is just opposite to that one for lead and zinc anomalous areas. Two important geochemical paragenetic associations are revealed: (1) Zn-Pb-Cu (\pm Ni) and (2) Cu-Ni (\pm Cr or V). The first association is the most common and it is chiefly this one to substantiate the existence additionally of a Polymetallic Province in Northern Somalia. The most samples with high Cu-Ni anomalous concentrations are from the areas of occurrence of basic rock environment. The copper anomalies seem to be not dependable clearly on the geological situation. Although the slight tendency to occur more frequently in the

synclines, quite a number of them were found in anticlines over the entire volume of the Basement. The cursory outline of the copper mineralizations shows that the synform structures more often than not are the places of the preferred concentration of copper occurrences. The above is true for the Cu- and most of the Cu-Ni associations. As the Cu-Mo associations are concerned they are related predominantly with the antiformal structures (for instance to the Southern anticlinorium). The Zn-Pb-Cu associations appear to depend also strongly on the rift structures. Certainly the lack of known deposits approaching economical proportions prevents from making satisfactory interpretations of the available geochemical data. In spite of this limitation, the available geochemical data on the revealed anomalous areas could be used, as to assist in understanding of metallogeny of Northern Somalia. These anomalies are probably favourable indications on the estimations of the general metallic prospects.

A few of the hydrothermal metallic occurrences were investigated properly. Much detailed work remains to be done before a complete and accurate picture of environment of the ore points can be presented with confidence. Nevertheless the outline given in the present paper emphasizes several undeniable facts which are summarized with the hope that they will be useful for further more detailed metallogenetic generalizations for this part of Somalia.

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