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COMPILING OF LITHOLOGOSTRATIGRAPHIC-TECTONIC SECTIONS, INCREASE SUBSTANTIALY RESOURCES OF CU-FE, CU-FE, ZN, AU, AG SULPHIDES HOSTED BY VOLCANOGENIC MASSIVE SULPHIDE DEPOSITS (VMS), IN ALBANIAN OPHIOLITES@

Lirim Hoxha, Consultant Geologist
Email: lirimhoxha@gmail.com, website: lirimhoxha.com

Regional geological setting

The Albanian ophiolites form an important link in the Alpine-Dinaride-Hellenide orogenic system.
Gawlick et al. 2014, based on abundant literature available for the palaeogeographic position of the Mirdita-Pindos ophiolites distinguish:
The Weastern Ophiolite Belt (central Dinaride, Mirdita, Hellenic ophiolites), the internal zones (Korabi-Pelagonian Microcontinent = Pelagonian zone, Korab zone, Drina-Ivanjica element) , the eastern ophiolites (Inner Dinaric ophiolite belt and Vardar zone) and the External zones.

There are two principial models:

a) An autochthonous oceanic domain between the Pelagonian/Korabi microcontinent to the east and "Adria" to the west;

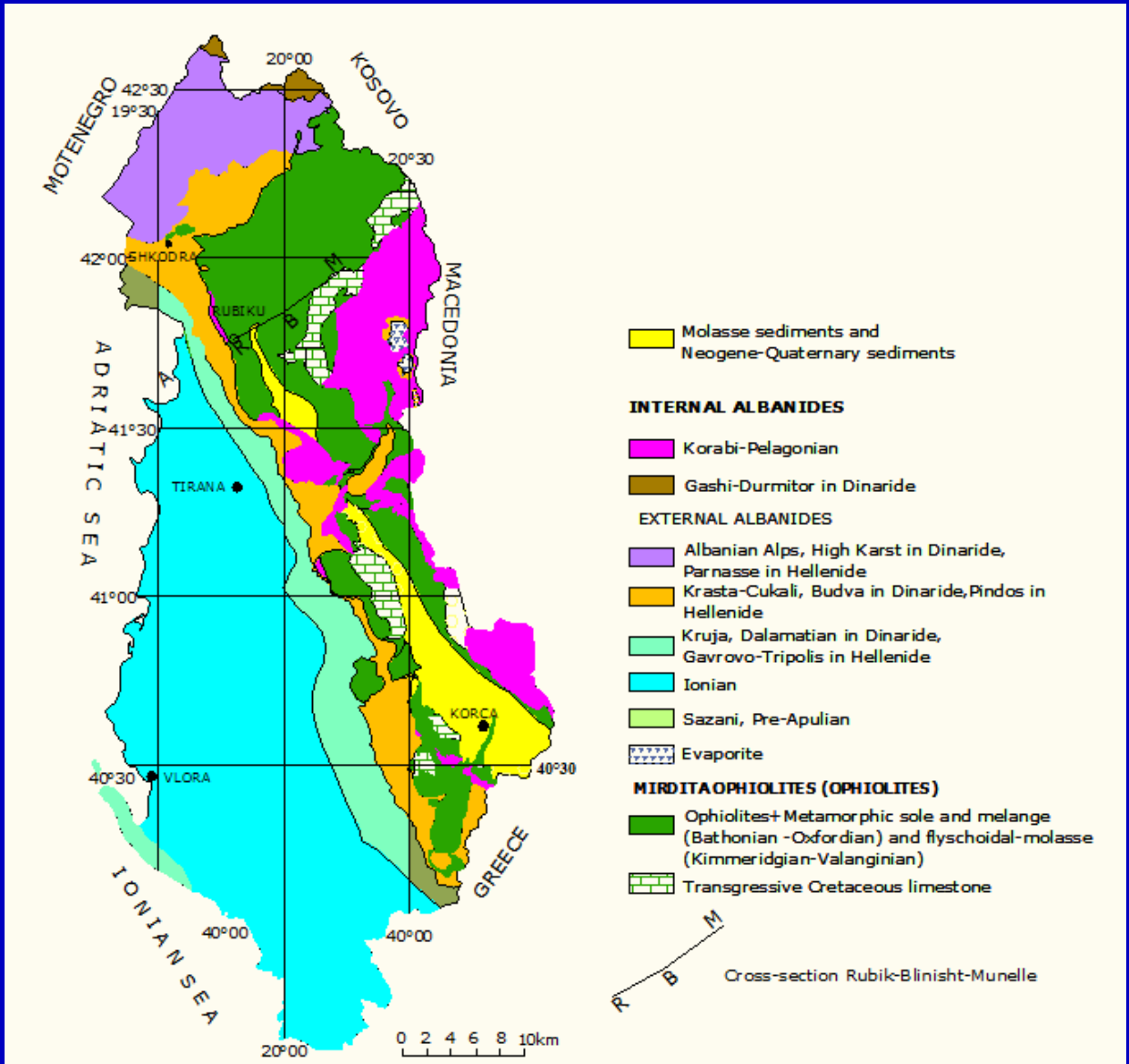
b) An allochthonous position: the ophiolite nappes derive from the east by westward obduction onto "Adria".
In addition, there is also a controversial discussion about the dipping of the (intra-) oceanic subduction:
East-dipping subduction within the Vardar(Maliac)/Neotethys Ocean;
West-dipping subduction in the Mirdita/Pindos Ocean

The detailed knowledge of these mélanges with "exotic" Triassic components in between the oceanic remnants of the so called Mirdita-Pindos Ocean is crucial for the reconstruction of the geodynamic evolution of the whole Balkan area.

Based on field trips 2003- 2006 all over Albania is concluded that "Mirdita Zone ophiolites and associated sediments in Albania reveal Neotethys Ocean origin" (Gawlick et al. 2008).

Detailed prospecting and explorations of sulphide deposits hosted by Mirdita ophiolites, Albania, indicate for their westward displacement by polyphase thrusting tectonics (Hoxha,1988, 2001; Hoxha et al. 2006 and quoted references).

Simplified tectonic map of Albania, showing major units and equivalents in Dinarides and Hellenides



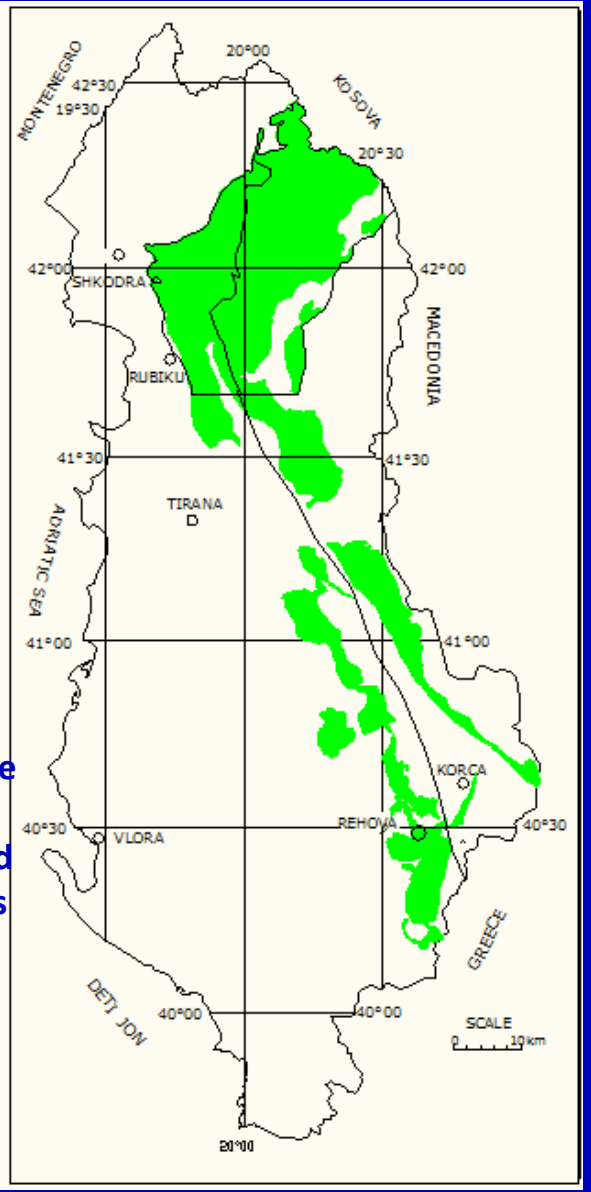
Tectonic Map of Albania. Simplified after Tectonic Map of Albania

Map of Albania with ophiolites. Thick line shows boundary between Western and Eastern Ophiolite Belts (After Geological Map of Albania 2002)

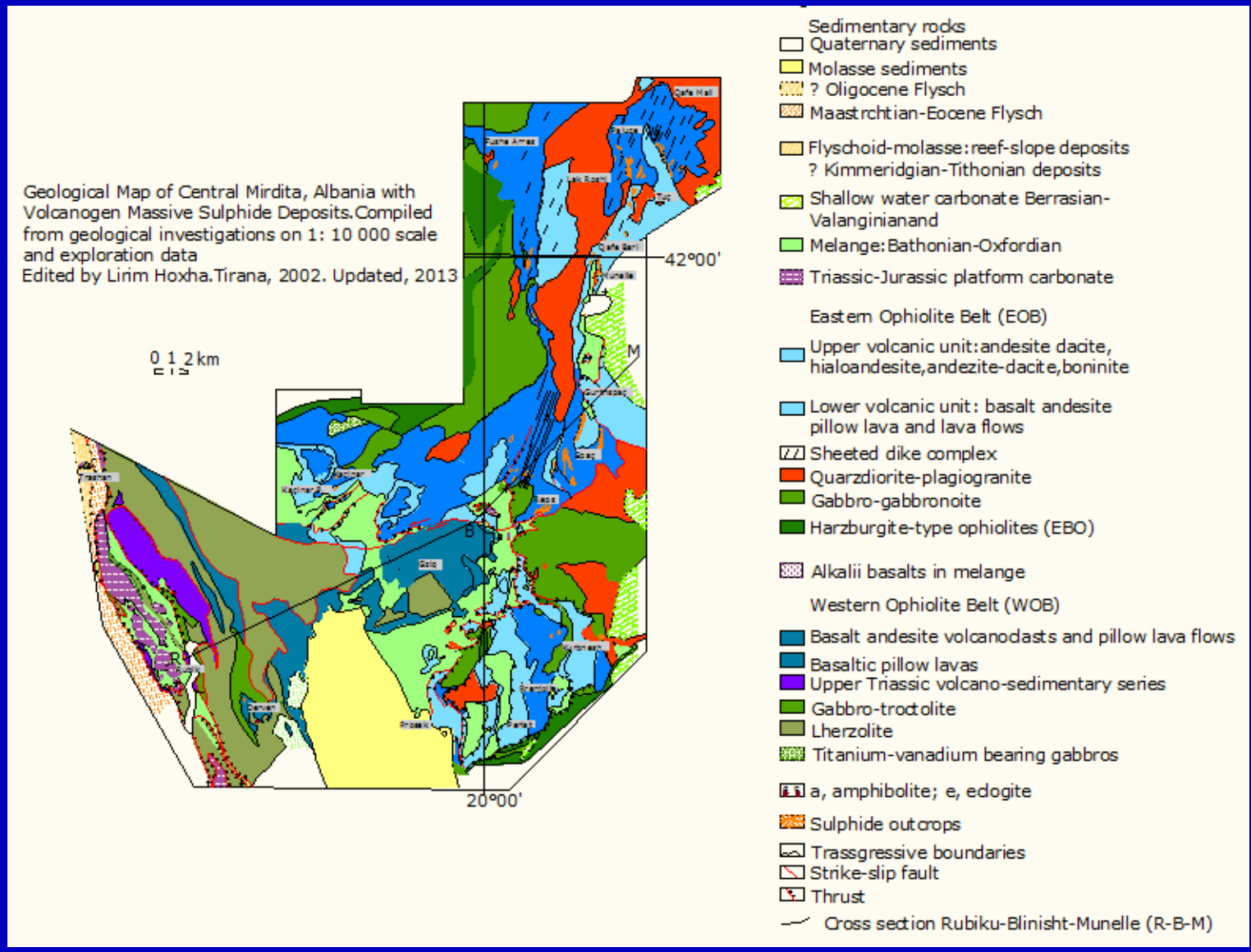
Shallo, 1994; Beccaluva et al. 1994; Bortolotti et al. 1996; Dilek et al. 2008 distinct Western Mirdita Ophiolites (WMO) and Eastern Mirdita Ophiolite Ophiolites (EMO) with an intact composite sections.

WMO comprises mantel tectonites (mainly lherzolite), plutonic complex (mainly gabbroids), very few plagiogranite intrusions and extrusive sequence of MORB-type basaltic pillow lavas overlain by chert and

EMO with mantel harzburgite, gabbroids plutons, plagiogranite-quartzdiorite intrusions, sheeted dyke complex and SSZ-type extrusive complex with lower part of basalt-andesite pillow lavas and upper part of basaltic andesites through dacites & bonintes



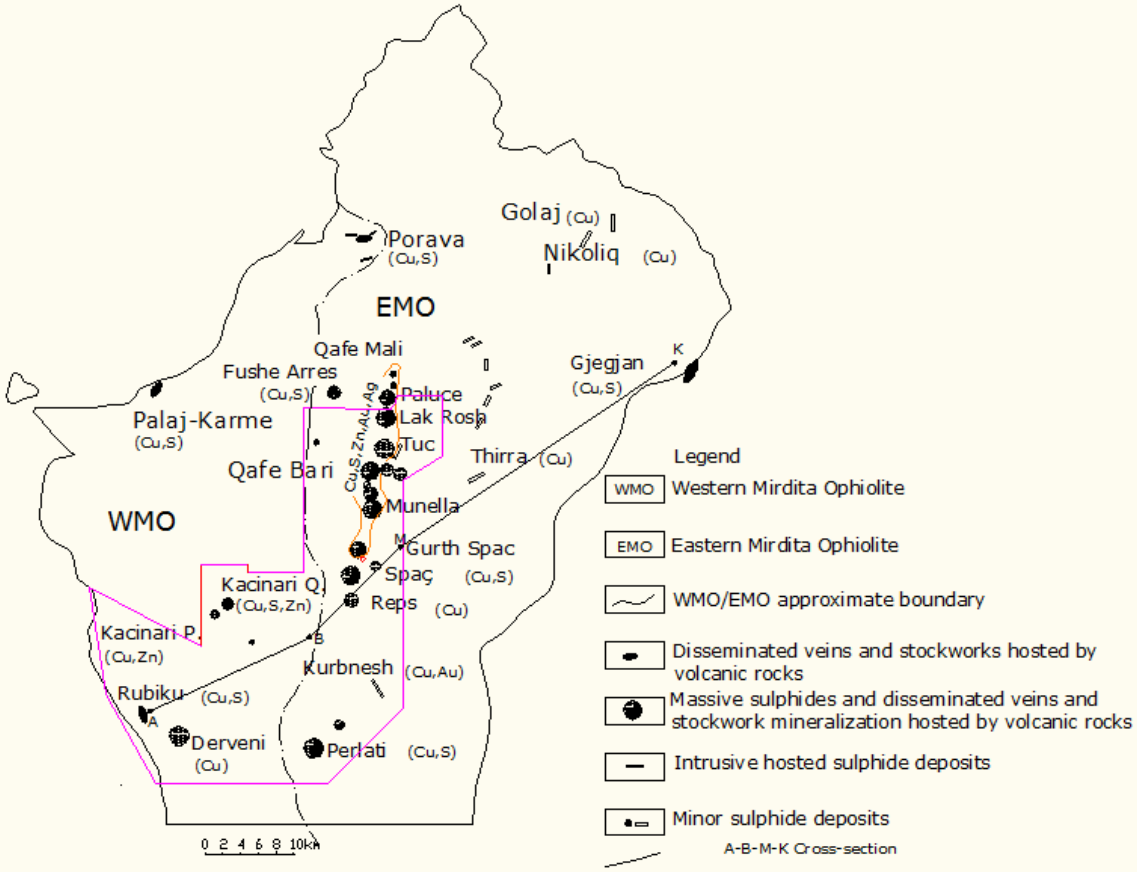
Geological Map of Central Mirdita with the western MORB-type and the eastern Supra subduction (SSZ)-type extrusives hosting Cu, pyrite/Zn, Au and Cu, Zn, Au, Ag and pyrite ores, plutonic-intrusive complexes, melanges and sedimentary rocks



The rock units are dismembered and westward displaced by polyphase thrusting tectonics. Boundary between Western Mirdita Ophiolite and Eastern Mirdita Ophiolite is through a thrust, complicated by a strike-slip fault.

In Albanian ophiolites are discovered more than 66 Mt sulphide Cu, pyrite/Zn and Cu, Zn, Au, Ag and pyrite ores. 50 Mt (75%) hosted by EMO (mainly volcanics), 11 Mt (17%) hosted by WMO volcanics and 5.3 Mt (8%) as a huge tectonic slide in the melange.

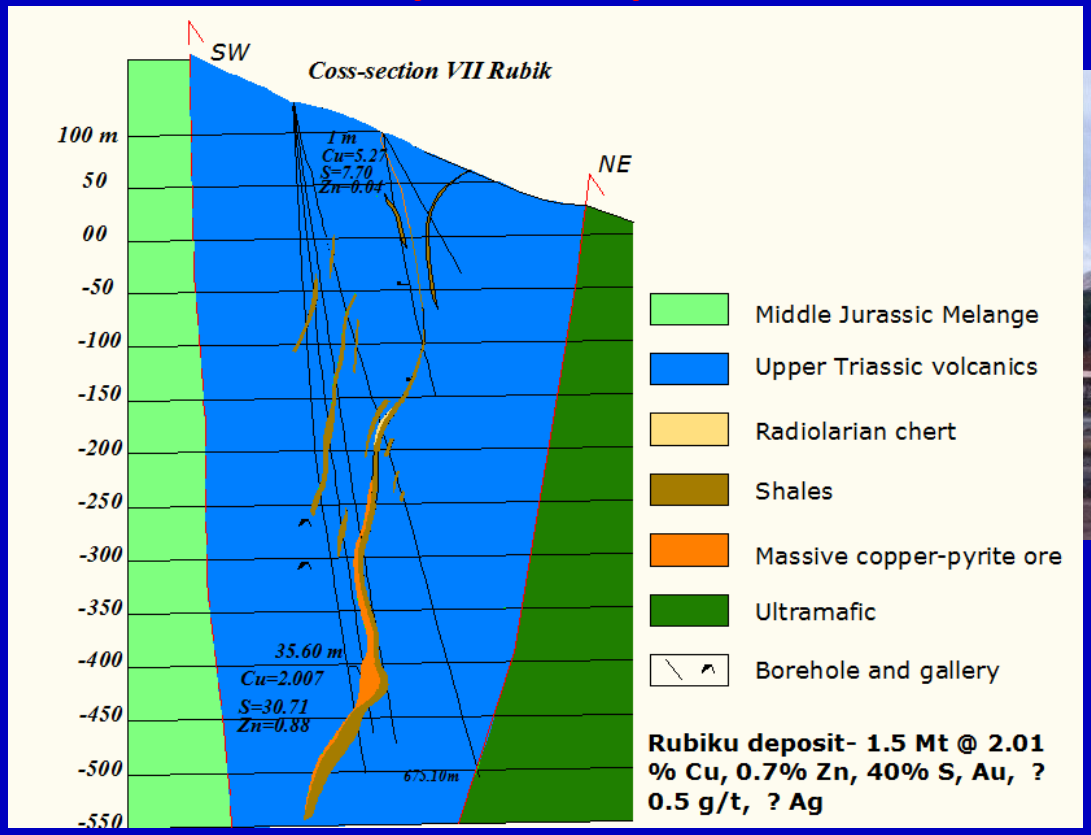
The sulphide orebodies range in size from thousands of tonns to 5 Mt in the WMO, comparable in size to modern sefloor deposits at ocean ridges and from thousands of tonns to 10 Mt in the EMO, similiar in size to suprasubduction environments.



Distribution of main sulphide deposits orebodies (named) and other minor deposits (numbered) within boundary of central-northern Albanian ophiolites. Poligon shows location of study area. Modified from Metallogenic Map of Albania 1:200 000 scale

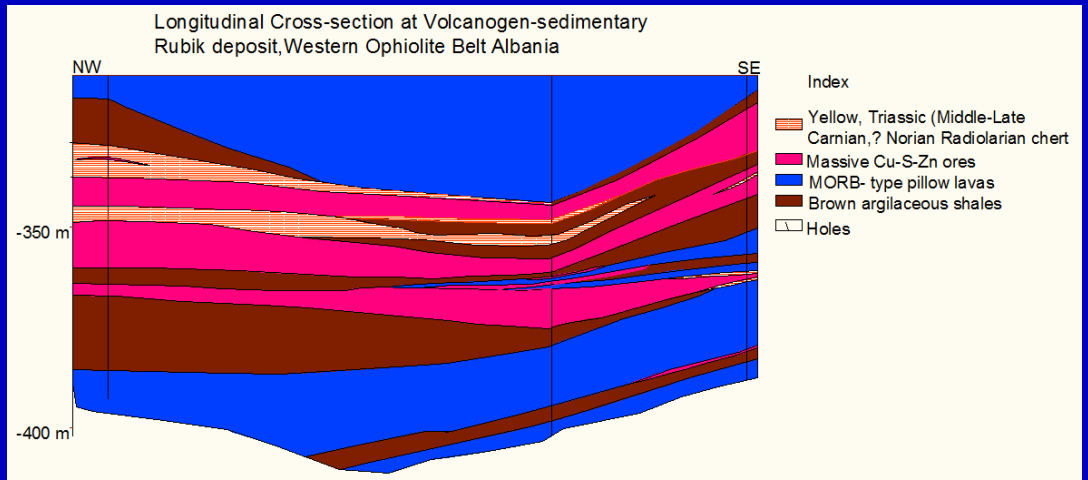
In the EOB , the orebodies are clustered along the genaral strike of the ophiolite similiar to those in the Troodos Complex of Cyprus and the Semail ophiolite of Oman.

Western Mirdita Ophiolite Belt- Rubiku deposit- Cu-pyrite-zinc ores hosted by volcanosedimentary series. Report on reserve calculation Hoxha and Gjeci , 1981

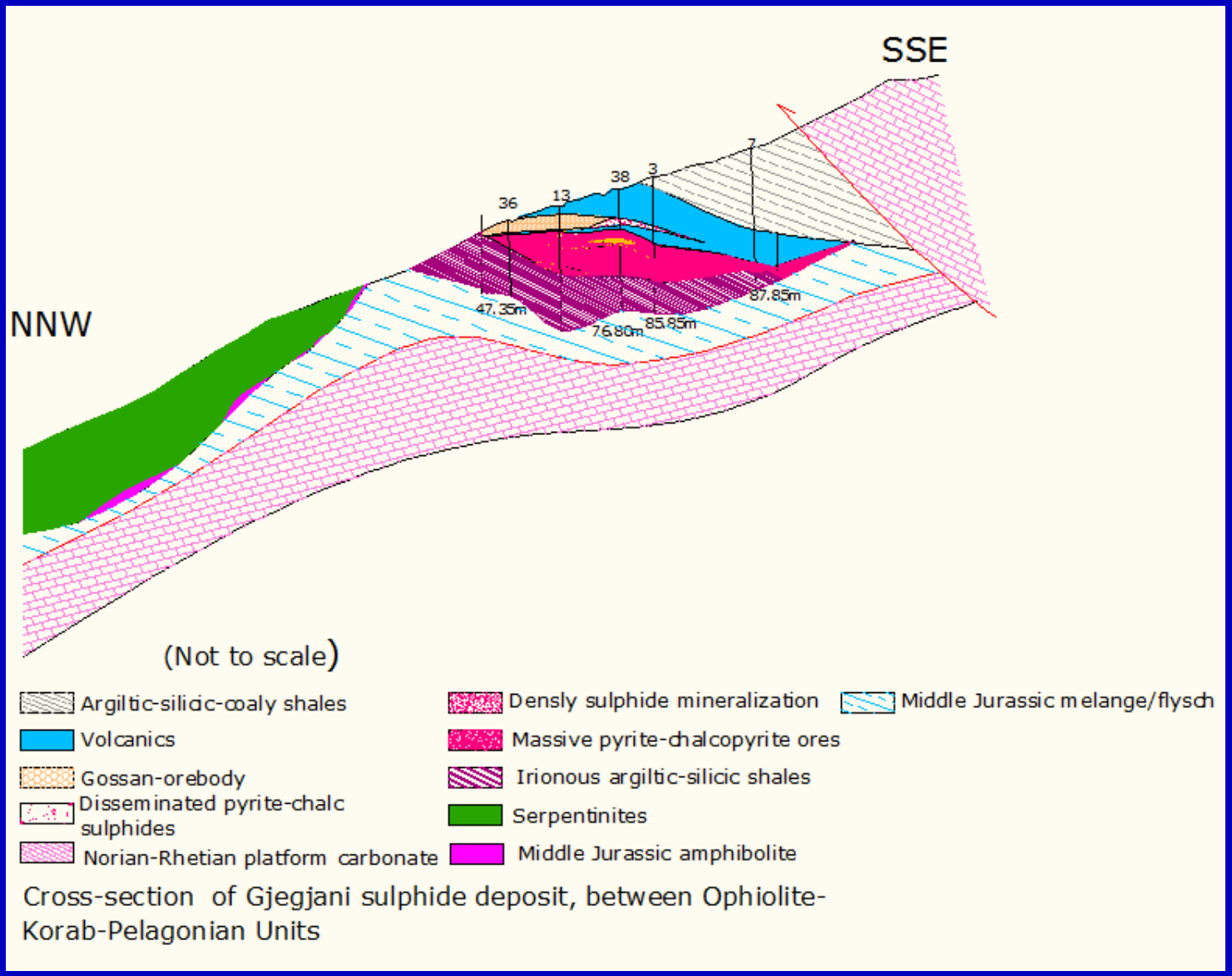


Rubik adit at Fandi River side
Triassic limestone on landscape

In WMO, the massive pyrite-copper ores are roughly lenticular, sheet-like or pipe-like, typically occurring between hematised Middle-Late Carnian age, probably including Early Norian radioarian chert (jasperoid) and tholeiitic basalt pillow lavas. Locally, intercalations of masive sulphides and volcanic strata occur. Disseminated droplet-veinlet Cu-Fe sulphides are found, too.
The shape of orebody is similiar with “black smoker” types from East Pacific Rise described by Hannington et al. 1995)



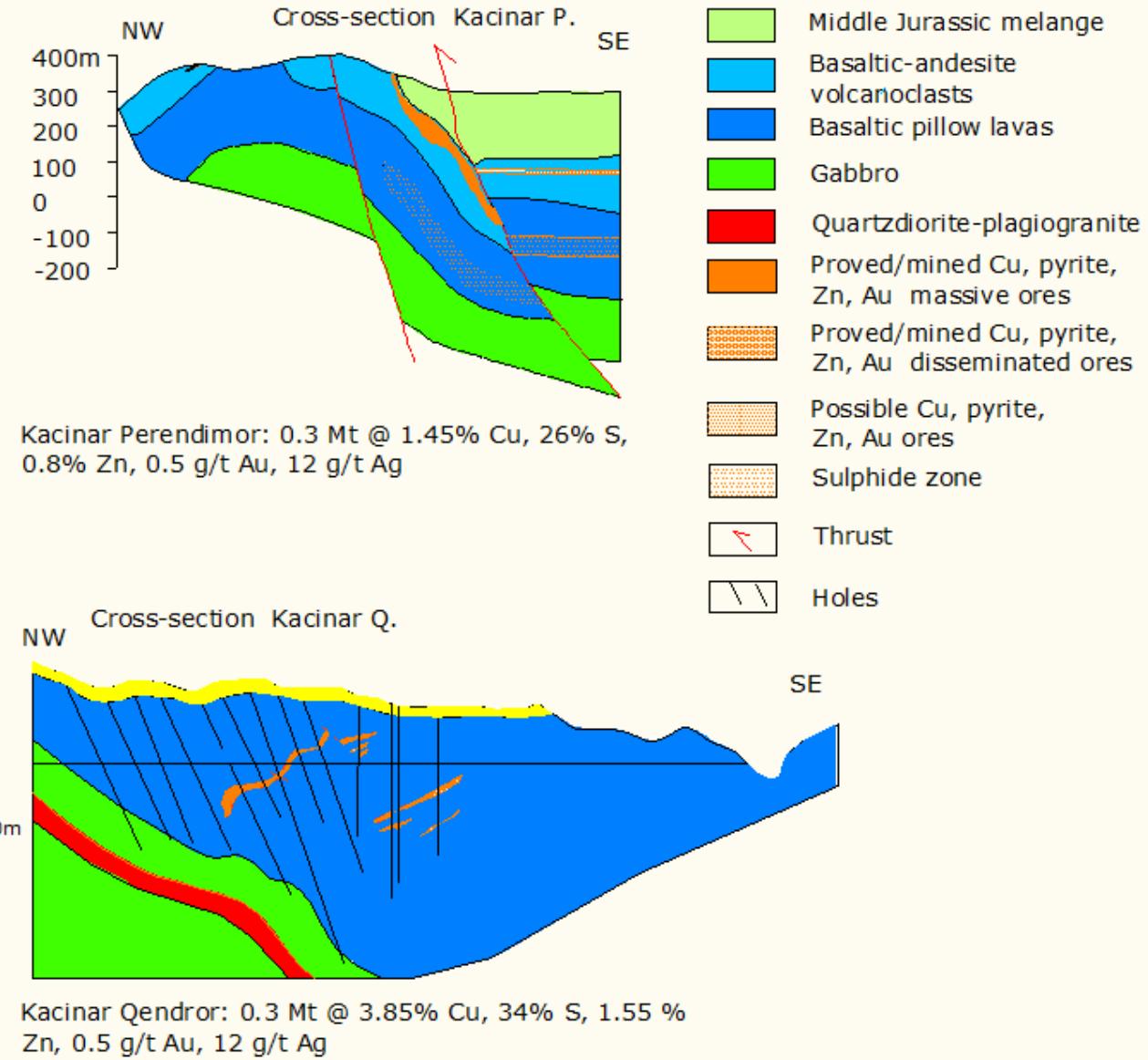
Gjegjani sulphide deposit (5.3 Mt @ 3% Cu; 38% S and 0.5 gr/t Au) located in melange, sandwiched between serpentinites with amphibolitic sole and Upper Triassic-Jurassic carbonate platform carbontates. Uplift of Upper Triassic limestones is shown, too.



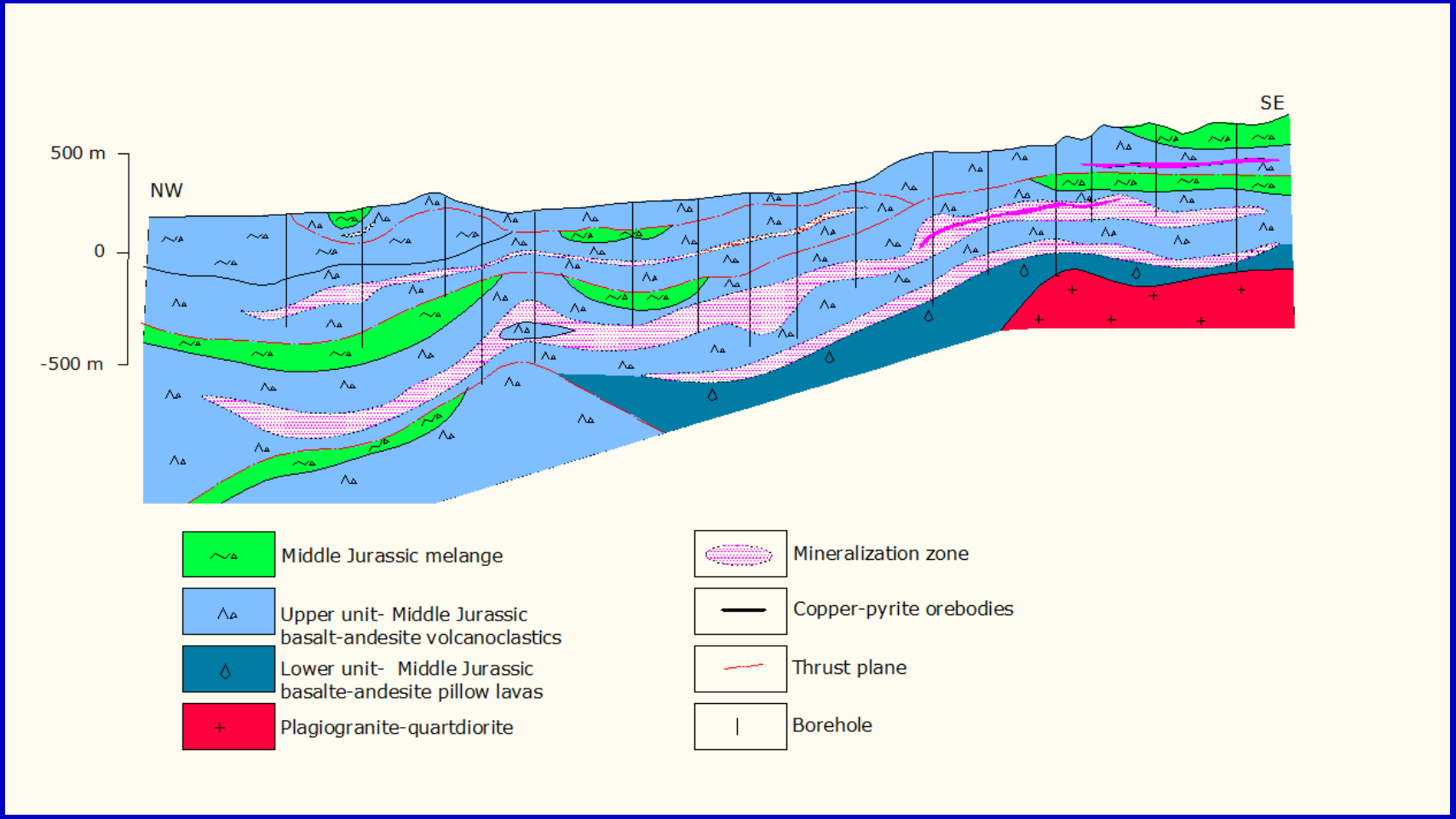
Cross-section of Gjegjani sulphide deposit, between Ophiolite-Korab-Pelagonian Units

A large, pyrite and chalcopyrite lenticular orebody (virtually depleted) up to 20 m thick, 300 X 400 m in lateral extent, is located between basalt lavas and melange.

Kacinari deposit-massive copper-pyrite/Zn, Au ores are hosted by basaltic-andesite pillow lavas and disseminated Cu, pyrite, Zn, Au ores are hosted by basaltic-andesite volcanoclastics (Hoxha, 1970 with updated information to 2002)

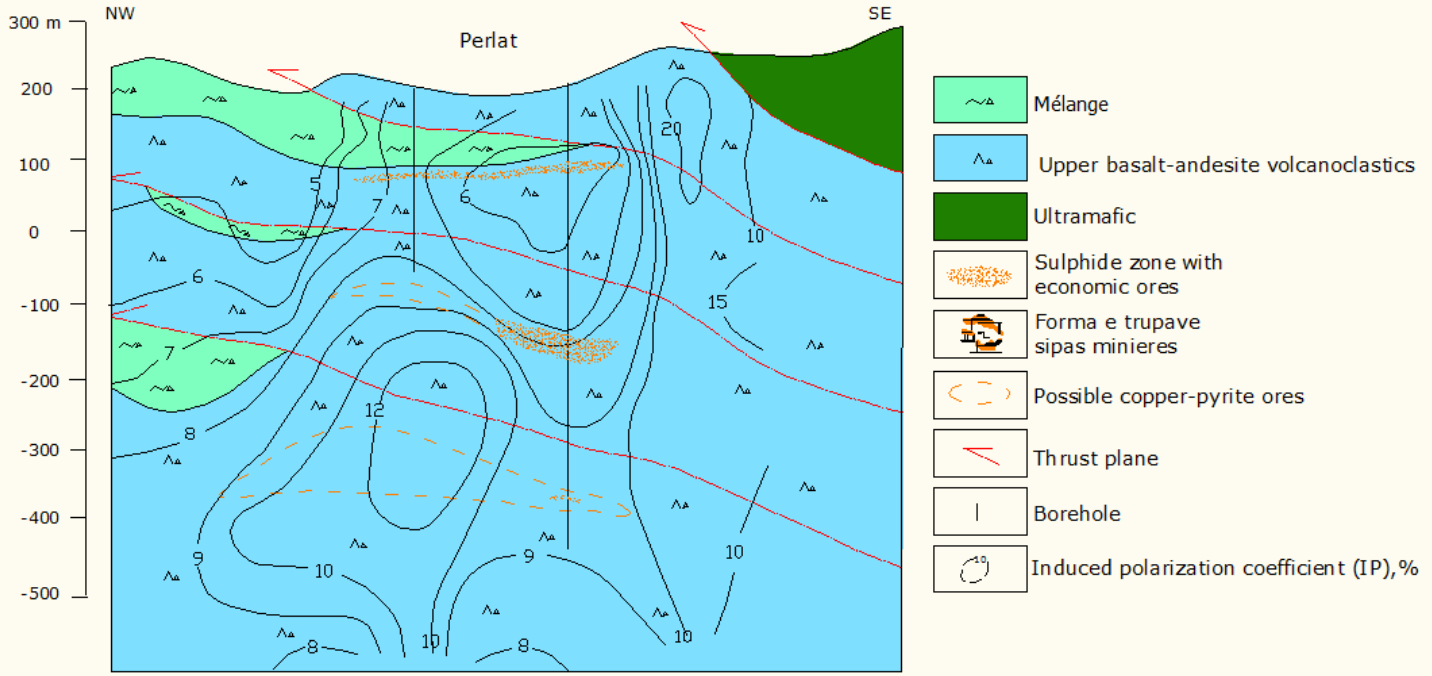


Perlat deposit 3.5 Mt@ 2.6% Cu, 0.2% Zn, 0.4 gr/t Au, 15 gr/t Ag (Hysi 1974; Doda, 1983; Daci 1986, Zaçaj, 1987)

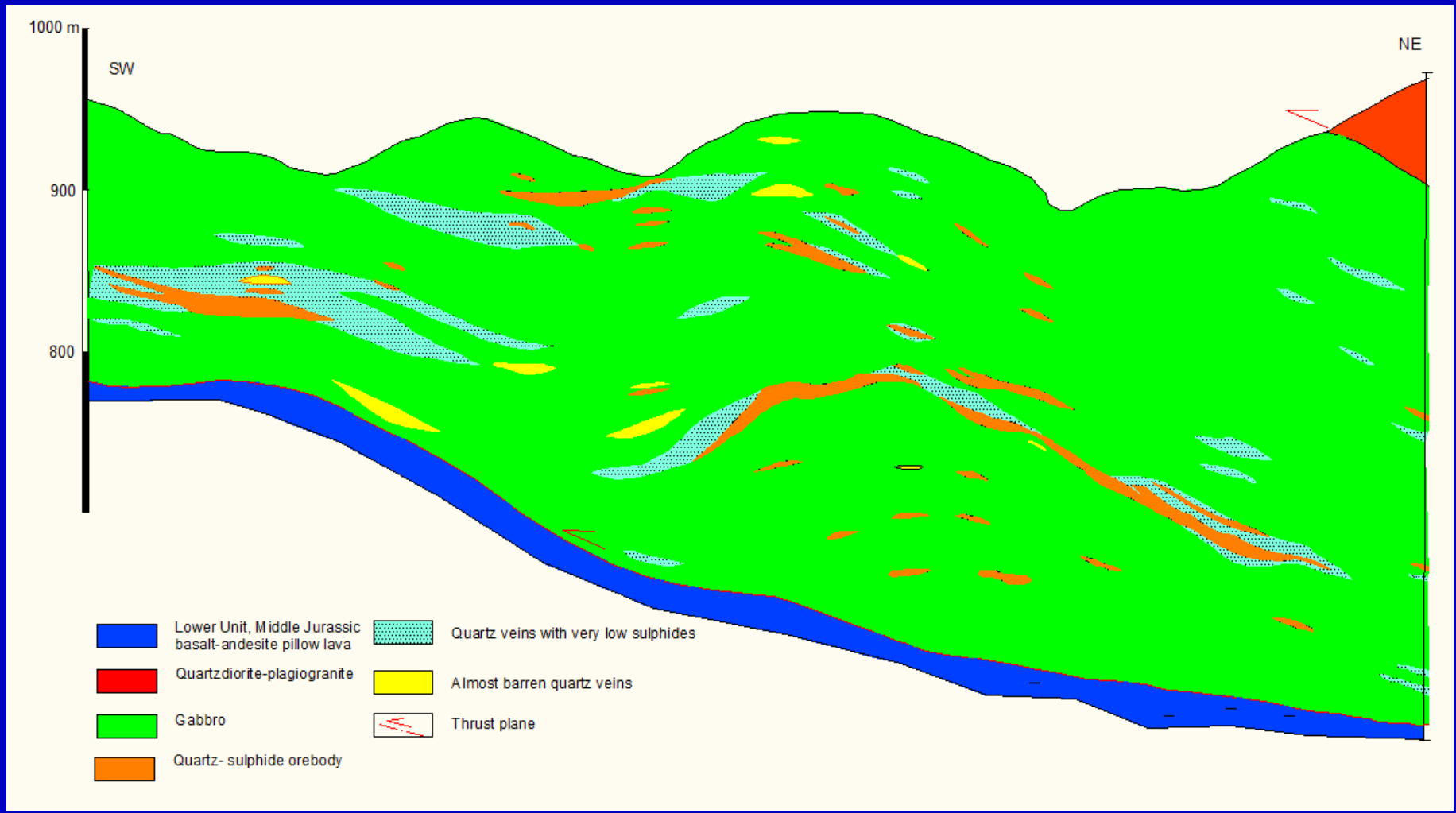


Longitudinal cross-section Perlat deposit showing repeated sulphide mineraliaztion due to thrusting tectonics (After Hoxha et al. 1988; Hoxha, 2001, 2005)

Peralt deposit, (a) Cross-section showing induced polarization contours, and repetition of ore bodies created by poliphase thrusting tectonics (Hoxha, 2001, 2005 and quoted references) (b) Detailed cross-section of orebody, taken from mining data

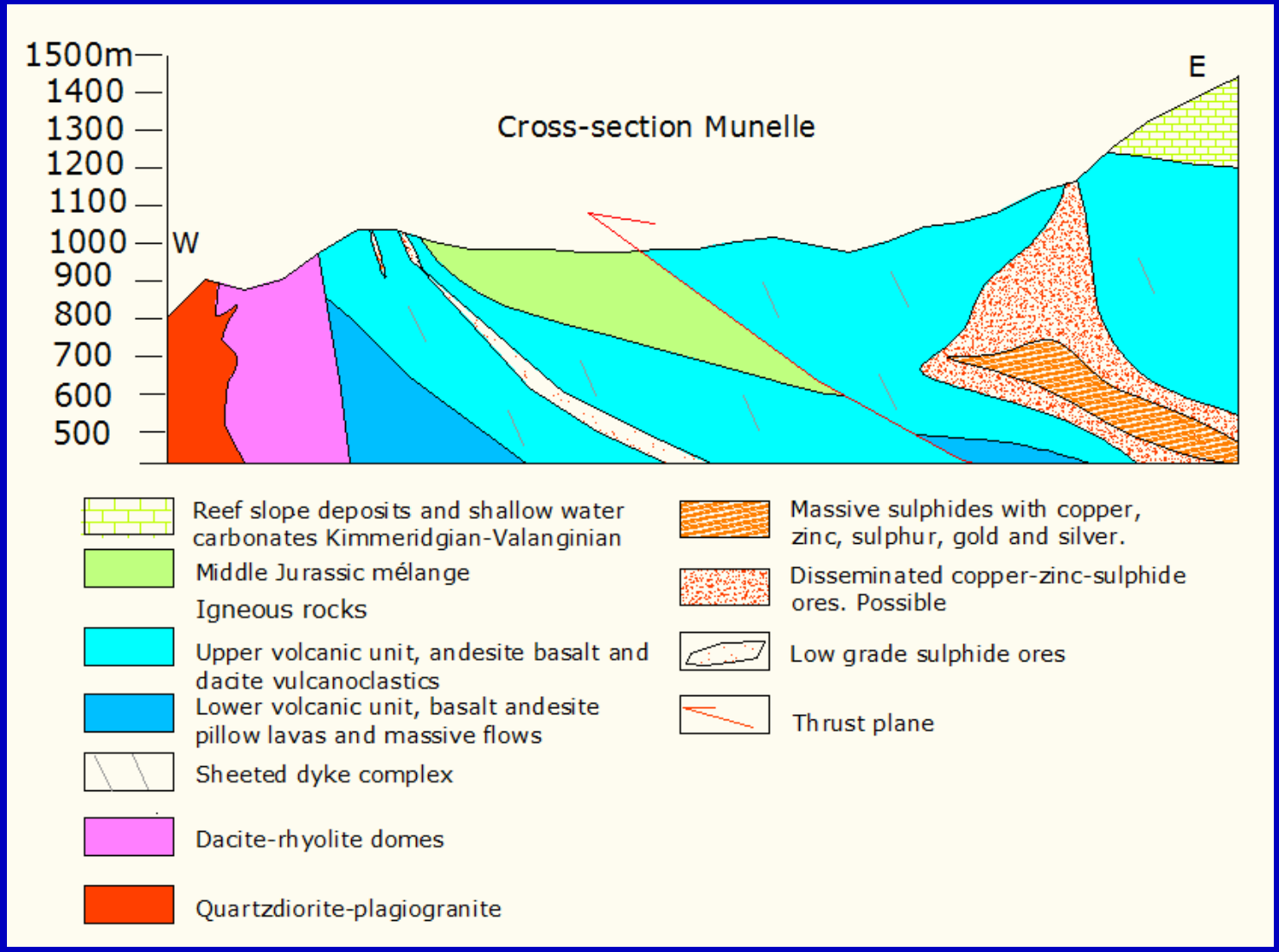


Kurbnesh, 3 Mt @ 2% Cu, 0.05-0.1% Co and about 1 gr/t Au (Jorjani, 1968 amd quoted references 1955-1968). In some orebodies gold has been 3-5 gr/t). Mined. Remained reserves about 50 000 tons. Longitudanal Cross-section based on exploration data 1995-1968 with updated information for thrusting tectonics (Hoxha, 1988,; Hoxha et al. 1999, 2001, 2005)



Eastern Mirdita Ophiolites

Munella Cu-Fe, Cu-Zn-Au-Ag ores (8.6 @ 0.975% Cu,;2.62%Zn, 0.53 gr/t Au, 15 gr/t Ag
(after Kamberaj and Bardhoshi, 1980; Zoi and Kamberaj, 1984)

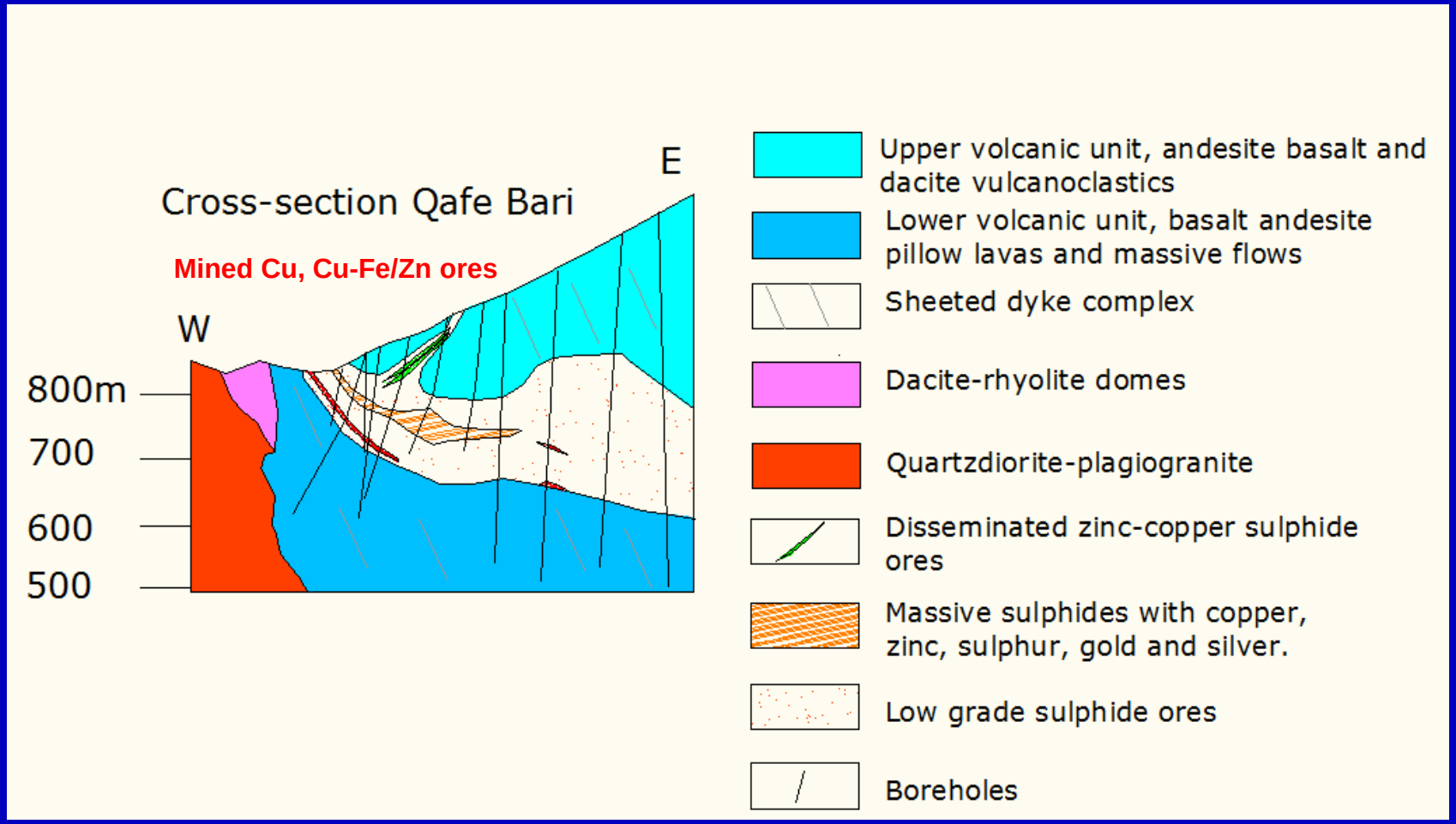


The major minerals are pyrite, chalcopyrite and sphalerite; in low quantities tennantite-tetrahedrite series as well as bornite and covellite (Kati and Koci, 1980)

Simplified cross-section with updated information to 1989 from Lleshi and Leka , 1988; Deda, **Hoxha L. 2001, 2005**.

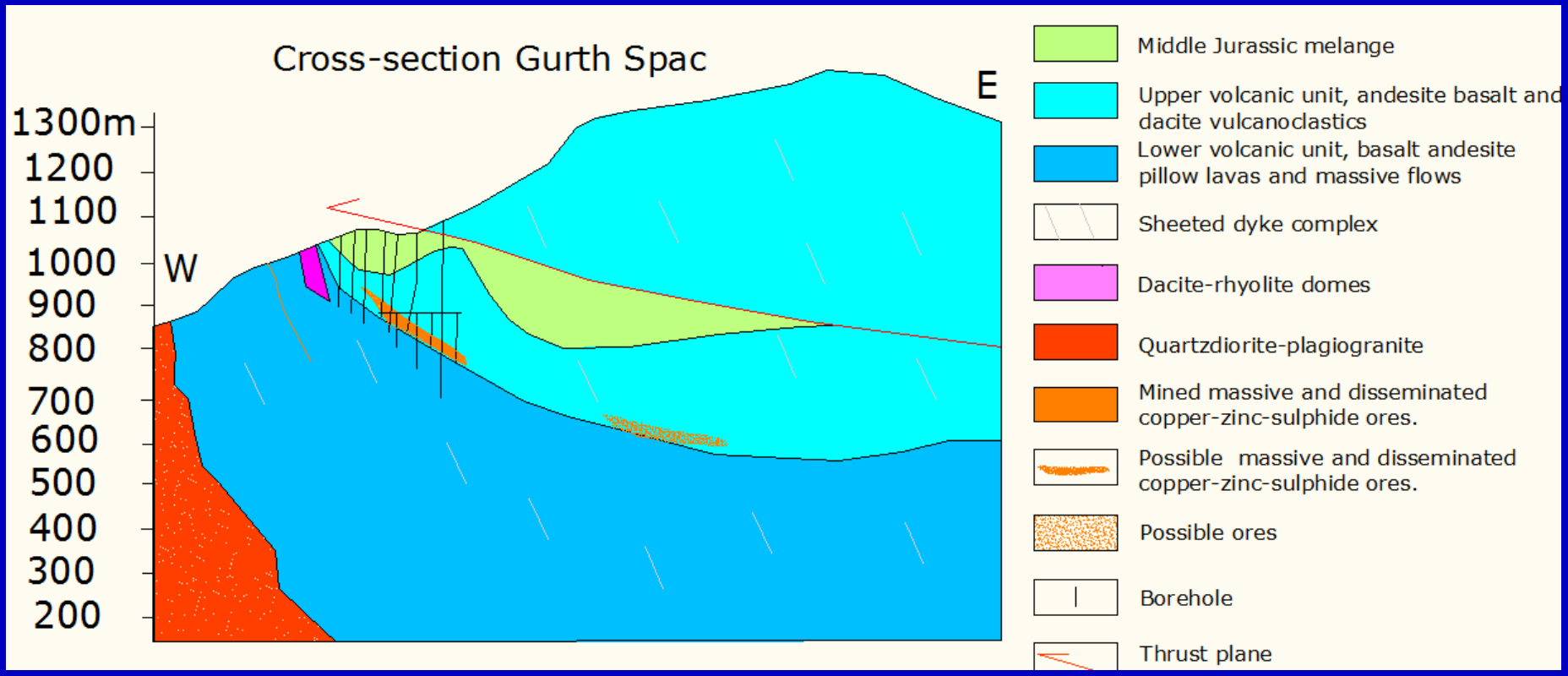
Qafe Bari- Cu-pyrite massive ores, locted in the Lower basalt andesite pillow lavas and covered by Upper andesite basalt and dacite volcanoclastics

3.6 Mt @ 2.14% Cu, 0.15% Zn, 29.5%S, 0.0023 %Co, 0.5 gr/t Au, ?Ag



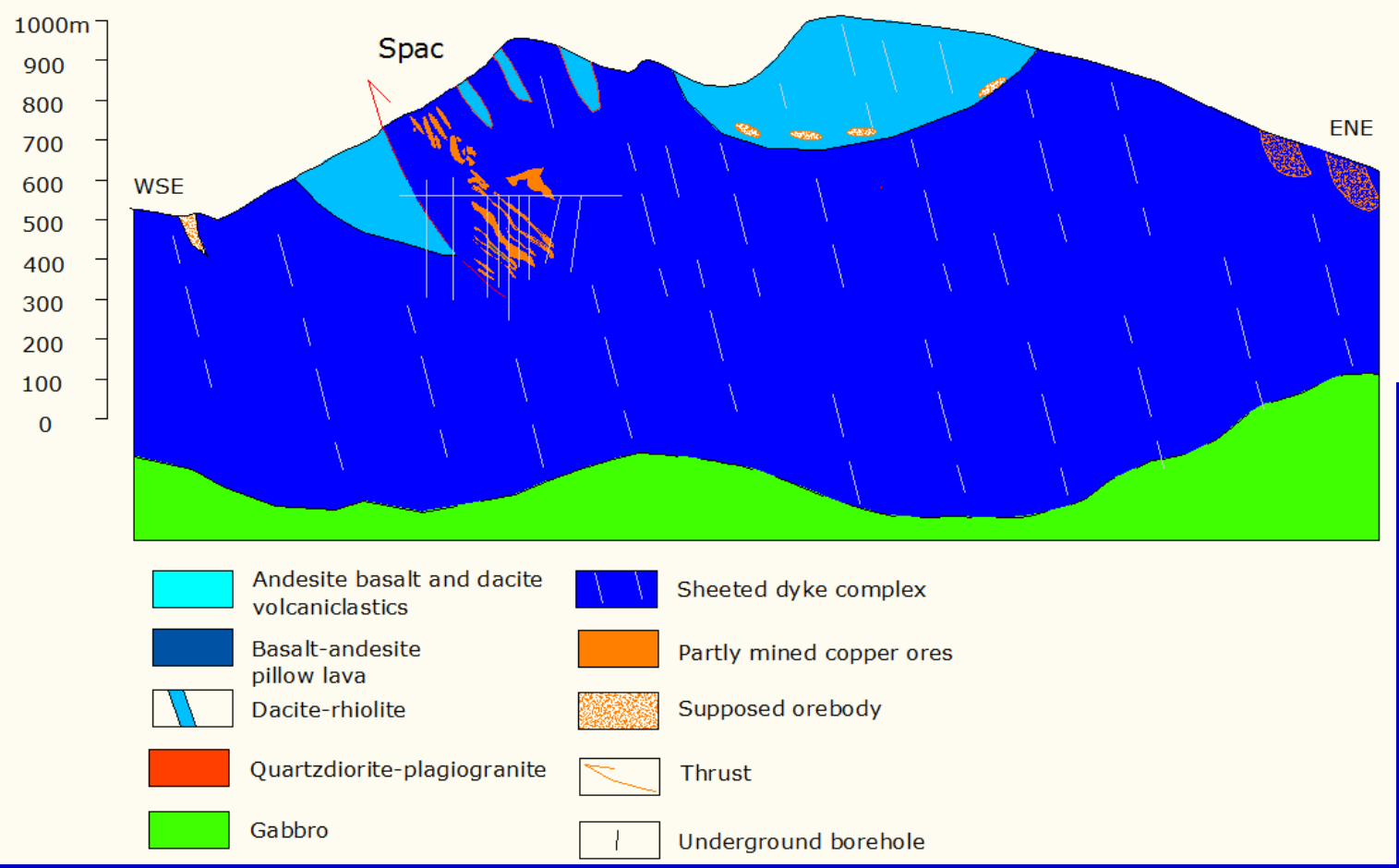
After Kokona, 1973 with updated information to 2002

Gurth Spac , 2.7 Mt @ 1.25% Cu, 2.62% Zn, 19% S, 0.55 gr/t Au, 15 gr/t Au (after Llubani, and Kodra, 1973; Llubani and Zaganjori, 1984).
Unmined Cu, Zn, Au, Ag reserves (Gurth Spac 1, 2 and 3) are evaluated to be about 0.4 Mt.

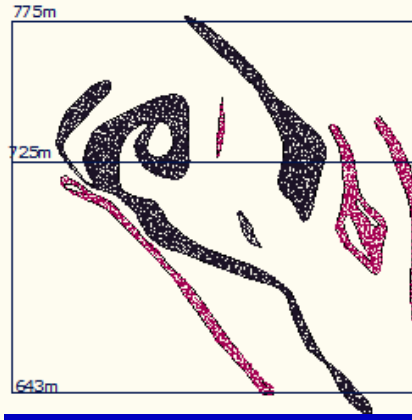


Cross-section showing location of ores and westward thrust of upper volcanic unit onto the melange (after, Hoxha, 1987, 2001, 2005) with updating information 2013.
Last years data indicate for much higher content of Au, Ag and Zn.

Spaci- Total reserves have been 7.41 Mt @ 1.27% Cu, 0.6% S, 0.002% Co and 1.71 Mt@ 0.33% Cu, 44.89% S and 0.04% Co (Shima, 1973; Kolndreu and Sulejmani, 1984).
Mined ores have been about 3.058 Mt @ 0.884% Cu (Bazhella, 2004)
Reserves as 01. 01. 2000 is about 6.06 Mt@ 1.158% Cu (Hoxha and Ndreca, 1987)
Averaging 0.011% Te and 0048% Se are present. At an extend, the size of orebodies has been determined by high cut of grade (> 1.2%) and many times low core recovery in exploration during 1950-1960s.



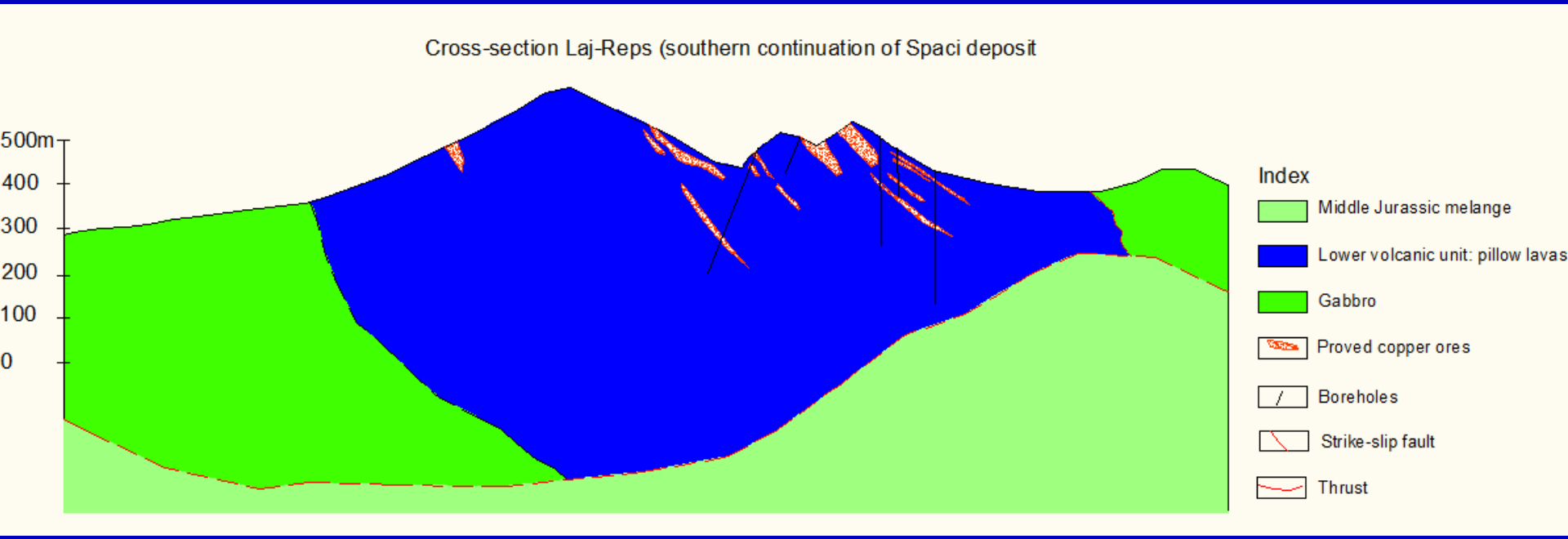
a. Cross-section Spaci deposit



b. Folding of massive pyrite and copper ores with westward vergence

Stockwork and disseminated copper, considered to be analogues with porphyry copper deposits (Hoxha, 1987, 2005; Hoxha et al. 2005) and massive pyrite ores are hosted by Lower Unit of basalt-andesite pillow lavas thrusted onto andesite-dacite volcanoclastics

Thrusting of of Laj-Reps deposit (southern continuation of Spac) with disseminated copper ores onto Middle Jurassic melange.
1.1 Mt @ 1% Cu.



Comparision of Idealised ophiolite sequence (Galley and Kosky, 1999) with lithologic and mineral deposits columns of Troodos, Cyprus (Constantinu, 1980(in, A.Robertson and X. Xenophontos,1993) and Semail, Middle East (D.A.F. Bachelor, 1992) ohiolite sequences, both Cretaceous in age.

Idealized ophiolite sequence

Seismic ocenic layers

Crust

Mantel

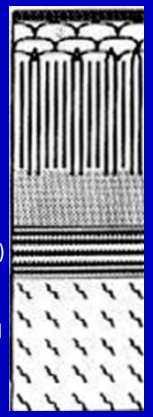
Layer 1 Sediments pillow lava and dikes

Layer 2

Layer 3 Cumulate (basic)

Layer 4 Cumulate (ultrabasic)

Tectonized peridotite



A)

Mineral deposits

Massive sulphide deposits

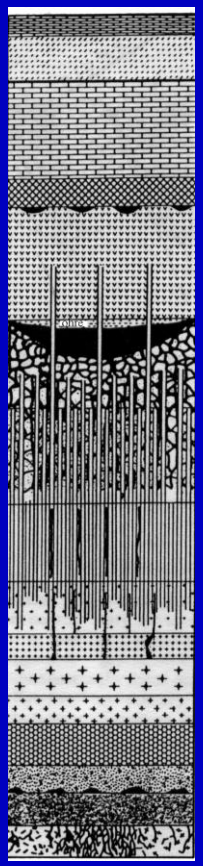
Sulphide minerlazation (crack filling) Fe – Cu

Sulphide mineralization (Fe- Cu- Co- Ni)

Chromite

Asbest

Stockwork mineralization



Rock types

Korona limestone

PAKHNA Formation

LEFKARA Group

PERAPEDHI Formation Umber

Lower pillow lavas

Basal Group

Diabase (Complex of parallel intrusions)

Plagiogranite

Gabbro

Ultrabasic sequence

B) Cyprus

Mineral deosits

Phase III Stockwork mineralisations 7 (Fe-Au- (Cu)

Massive sulphide mineralizations Fe-Cu- Zn- Au- Ag

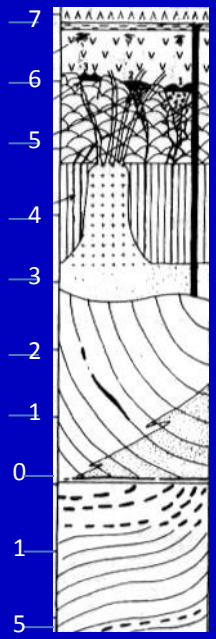
Stockwork mineralizations Crack filling with Cu- (Ni)

Magmatic sulphide mineralizations Cu- (Au-Pt)

Type I of Stratified chromites

Type II of tabular and podiform chromites

Type III of chromites of deep mantle



Rock types

Upper volcanic unit (V3)

Lasahel unit

Pelagic sediments + metalliferes

Middle volcanic unit (V2)

1.Bayda 2. Lasail 3. Aarja

Lower volcanic unit (V1Geotimes unit)

Stratified dike complex

Later intrusive complex (plagiogranite – diorite - gabbro)

Upper level gabbro (isotropic gabbro)

Stratified gabbro

Stratified unit "Seismic Moho"

Stratifie ultramafic rocks

"Petrologic Moho"

Mantel tectonite (Harzburgite- dunite)

C) Semail

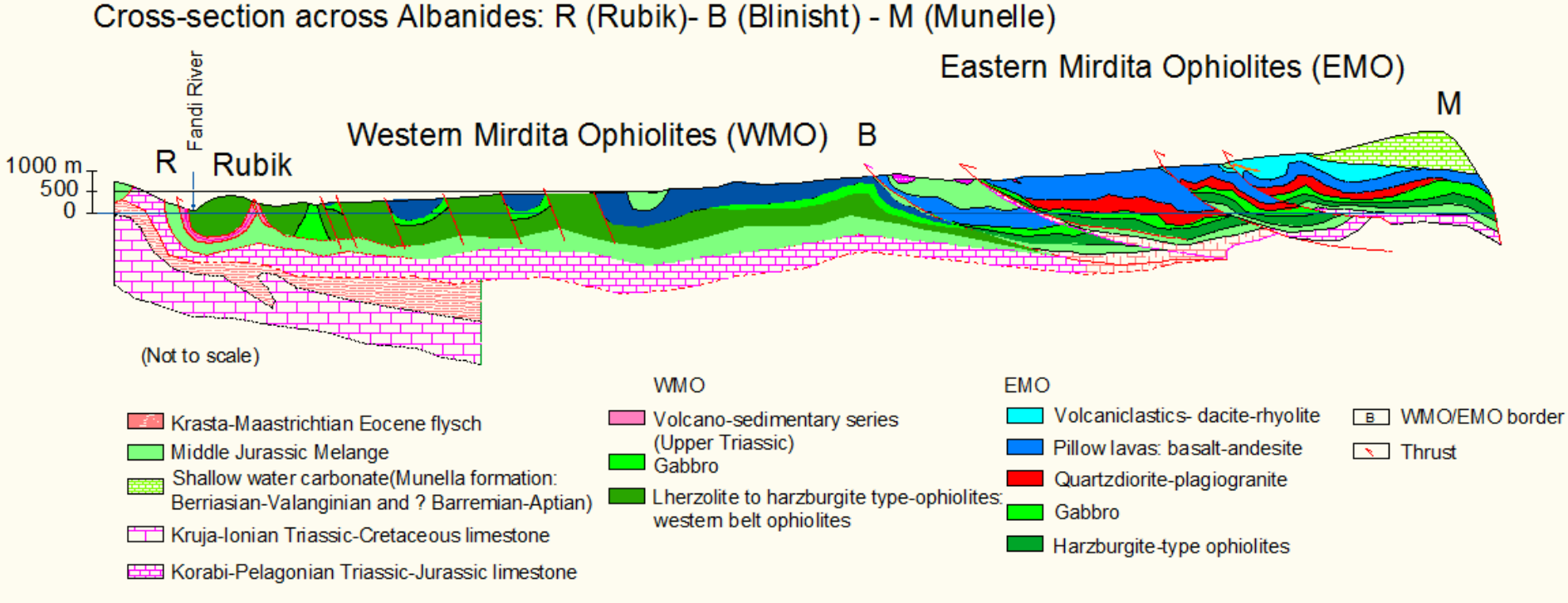
The Cyprus and Semail ophiolite sequnces are intact

Cross-section through Western Mirdita Ophiolite (WMO)–Eastern Ophiolite Belt (EMO) showing main orogenic events:

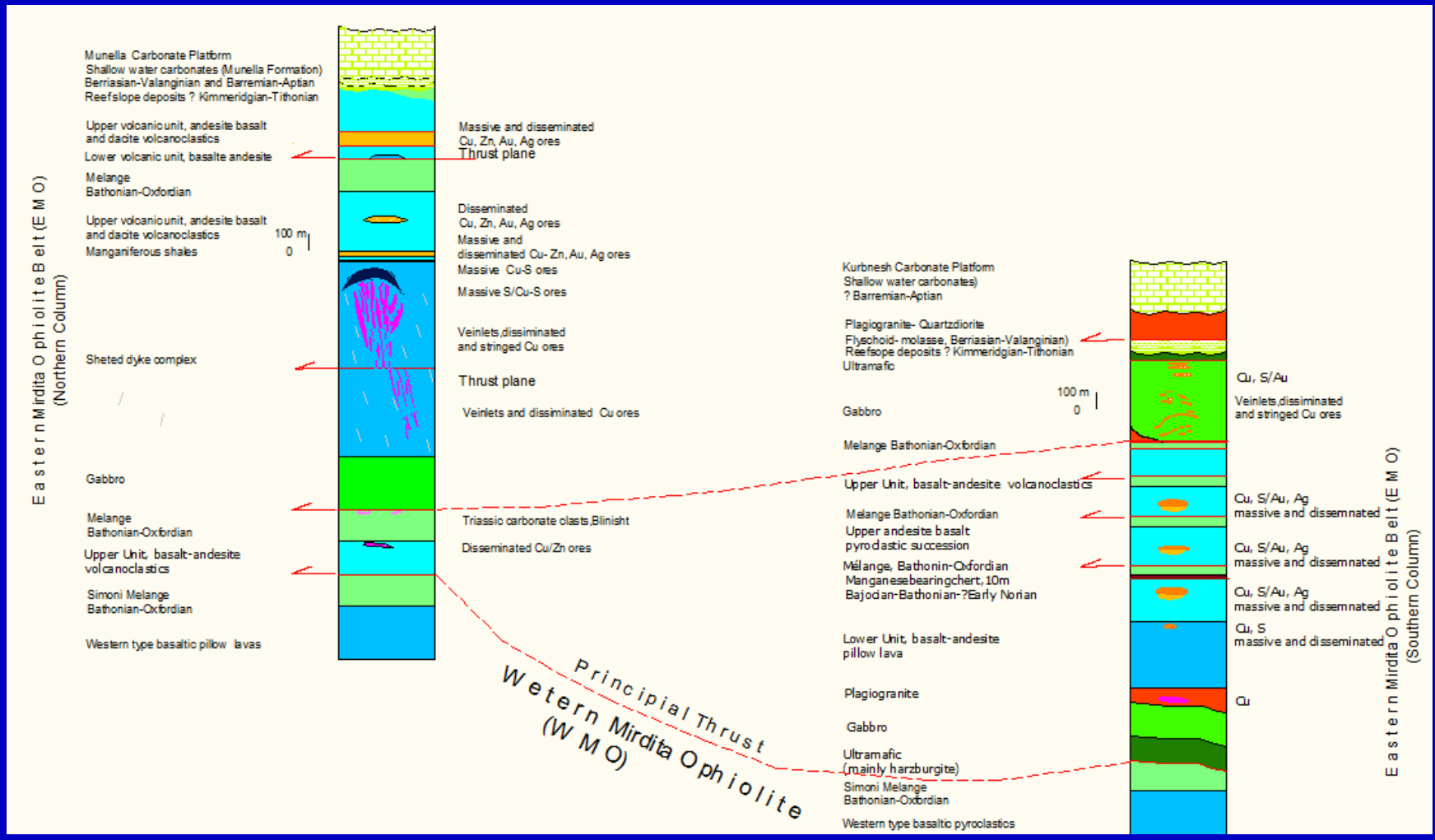
a) westward thrusting of WMO Nappe onto the mélange underlein by Triassic-Jurassic limestone;

b) westward thrusting of EMO Nappe onto WMO Nappe overlain by Bathonian–Oxfordian mélange/flysch, associated with a stack of thrust sheets;

Orogenic movements terminate with transgressive Kimmeridgian-Tithonian and Barremian-Aptian transgressive deposits.



Generalised Eastern Mirdita Ophiolite lithostratigraphic-tectonic sections with sulphide mineralizations. Figure shows polyphase westward thrusting of Spaci-Kurbnesh area onto Perlat area, which in turn, is thrusted onto Western Mirdita Ophiolite Nappe.
Big thrusts ar associated with a stack of polyphase smaller rank thrust sheets.



At Northern Column a hypogene sulphide zoning is distinguished: in the lower basalt andesite pillow lavas and sheeted dyke complex occur stockwork and disseminated copper ores, analogues with " copper porphyries", overlain by massive pyrite ores; at the upper part of andesite basalt and dacite volcanoclastics occur massive and disseminated copper, zinc, gold, silver ores.
At the Sourthern column, massive pyrite-copper ores are underlain by chloritization-sericitization zones containing gold .

Conclusions

- Cu-Fe sulfides with Zn, Au and Ag of Central Mirdita ore field, are hosted by Western Mirdita Ophiolites and Eastern Mirdita Ophiolites.

- Geodynamic evolution is characterised by following main orogenic events:

  a) westward thrusting of Western Mirdita Ophiolite Nappe onto mélange/flysch underlein by Triassic-Jurassic limestone;
  b) westward thrusting of Eastern Mirdita Ophiolites onto Western Mirdita Ophiolite Nappe overlain by Bathonian–Oxfordian mélange/flysch, associated with a stack of thrust sheets.
  Orogenic movements terminate with transgressive Kimmeridgian-Tithonian and Barremian-Aptian deposits.

- In Western Mirdita Ophiolite sulphides occur in extrusive sequence of MORB-type basaltic pillow lavas, whereas in EMO in Suprasubduction-type extrusive complex, as well as, in gabbroid plutons, plagiogranite-quartzdiorite intrusions and sheeted dyke complex.

- Based in different volcanic units and sulphide types, Eastern Mirdita Ophiolite volcanics can be diveded in two lithostratigraphic units:
  a) the Lower Unit of basalt-andesite pillow lavas hosting massive pyrite ores, underlain by disseminated veins and stockwork mineralization.
  With decrease of cut off grade for copper, the size and reserves of deposit can be increased significantly.
  b) the Upper unit of the andesite-dacite (rhyolite) volcaniclastics hosting massive and disseminated Cu, Zn, Au, Ag ores. In the sphalerite-chalcopyrite assemblange, the amount of tennantite-tetrahedrite minerals increas upwards, as do covellite, chalcosite, galena and, particulaarly, Au and Ag values.

- The west directed polyphase tectonics has seperated especially EMO different sulphide units creating high possibilitis for substantial extension against known ores.

- Compared with idealised ophiolite and lithologic and mineral deposits column of Troodos, Semail as well as all previousy published ophiolite columns of Albania, the ophiolite sections are highly dismemberd by polyphase tectonics, and in this point of view very important for exploration.

REFERENCES

BATCHELOR, D. A-F.,1992: “Styles of metallic mineralization and their tectonic setting in the Sultanate of Oman”. Appl. Earth Sci. (*Trans. Inst. Min. Metall. B*), 1992, **101**, B108-B130.

BAZHELLA, GJ., 2004: “Kultura Minerare ne Mirdite”. Shtepia Botuese Mirdita, 2004.

BECCALUVA, L., COLTORTI, M., PREMTI, I., SACCANI, E., SIENA, F., ZEDA, O.,1994: “ Mid-ocean ridge and supra-subduction affinities in ophiolitic belts from Albania”. In: Beccaluva, L. (Ed.), Albanian Ophiolites: State of the Art and Perspectives. Ofioliti, vol. **19**, pp. 77–96.

BORTOLOTTI, V., KODRA, A., MARRONI, M., MUSTAFA, F., PANDOLFI, L., PRINCIPI, G., SACCANI. E., 1996: “Geology and petrology of ophiolitic sequences in Mirdita region (Northern Albania)”. Ofioliti **21**, 3–20.

DACI, A.,1986: “Report on reserve calcuation Perlati deposit”. Archives of Albanian Geological Survey, Tirana.

Deda, T., Sinoimeri, A ., Lleshi, N., Leka, Gj.,1995: “Geological and mineralogical aspects of the Munella gold-bearing sulphide depozit. Workshopen Albanian ophiolites and related mineralization, IUGS/UNESCO Modeling Programme, PG. 78-79.

DILEK, Y., FURNES, H., SHALLO, M., 2008: “Geochemistry of the Jurassic Mirdita Ophiolite (Albania) and the MORB to SSZ evolution of a marginal basin oceanic crust. Lithos **100** (2008) 174–209

DODA, V.,1983: “Report of reserve calculation Perlat deposit”. Archives of Albanian Geological Survey, Tirana.

GALLEY, A.G. and KOSKY, R.A.,1999: “Setting and characteristics of ophiolite-hosted volcanogenic massive sulphide deposits”, Rev. Econ. Geol., 1999, 8, 221-246.

GAWLICK, H-J., FRISCH, W., HOXHA, L., DUMITRICA, P., KRYSTYN, L., LEIN, R., MISSONI, S., SCHLAGINTWEIT, F., 2008: “Mirdita Zone ophiolites and associated sediments in Albania reveal Neotethys Ocean origin”. Int J Earth Sci (Geol Rundsch) (2008) **97**:865–881

HANNINGTON, M.D., JONASSON, I.R., HERZIG, P.M. and PETERSEN, S.,1995: “Physical and chemical processes of seafloor mineralization at mid-ocean ridges”, (eds. S.E. HUMPHRIS, R.A. ZIERENBERG, L.S. MULLINEAUX and R.E. THOMSON), Seafloor hydrothermal systems “, Geophysical Monograph **91**, American Geophysical Uninon, 1995, 115-157.

HOXHA, L. and KOKA, A., 1970: “Report of reserve calculation Kacinari deposit”. Archives of Albanian Geological Survey, Tirana

HOXHA, L. and GJECI, K., 1981: “Report of reserve calculation Rubiku deposit”. Archives of Albanian Geological Survey, Tirana

HOXHA, L. and NDRECA, N., 1987: “Report of reserve calculation Spaci deposit”. Archives of Albanian Geological Survey, Tirana.

HOXHA, L., BERXHIKU, P. and DACI, A., 1988: “Effects of thrusting tectonics in exploration of sulphide mineralizations at Kurbnesh-Tarazh-Perlat area. Buletin i Shkencave Gjeologjike, 1988, **3**, 7-20. Tirana (in Albanian).

HOXHA, L., 1995: “ Sulphide mineralization of Albanian ophiolite volcanics”(Presentation at Int. Volcan. Congr. Ankara, 1994). Bul.Shk. Gjeol., 1995, Nr. **1**, 39-64.

HOXHA, L. and ZAGANJORI, B., 1987: “ Generalization study on sulphide zoning and expected reserves at Mushte-Gurt Spac-Spac-Laj Reps area. 89 pp. In Albanian. Archives of Albanian Geological Survey, Tirana.

HOXHA, L. and ZAGANJORI, B., 1998: “ Sulphide mineralization zoning of Sac-Gurthspac area (SZ Ophiolites, Albania): A case history “ PER.MINERAL., 1998, **67**, 87-93.

HOXHA, L., ZAÇAJ, H. M. and ONUZi, K., 1999: ” The effects of Jurassic-Cretaceous orogenic event in exploration of sulphide deposits, Albanian ophiolites, Albania”, Abstracts 4th Workshop, Alpine Geological Studies, Tubinger 21-24 Sept. 1999. *Tübinger Geowissenschaftliche Arbeiten, Series A*, 1999, **52**, 108-109.

HOXHA, L., 2001: “ The Jurassic-Cretaceous orogenic event and its effects in the exploration of sulphide ores. Albanian ophiolites, Albania” Eclogae. Geol. Helv., 2001, **94**, 339-350.

HOXHA, L., SCOTT, P. W. and EYRE, J. M., 2005: “The geological setting of volcanogenic sulphide orebodies in Albanian Ophiolites”. Applied Earth Science (Trans. Inst. Min. Metall. B) March 2005 Vol.**114** B33.

HOXHA, L., DEDA, T., LEKA, GJ., LLESHI, LL., BOSHNJAKU, B., SHTJEFANAKU, D., GJONI, S., 2005: “Geological setting, reseves and perspective of extension sulphide deposits (VMS) of Albania” (Joint Symposium of the Ministry Industry and Energy and Albanian Geological Survey. Tirana International Hotel, Tirana, Fushe Arres, June, llo, 2005)

HYSI, Sh. and JONUZI, S., 1974: “Report of reserve calculation Perlati deposit”. Archives of Albanian Geological Survey, Tirana.

Jorjani, V., 1968: “ Raport i llogaritjes se rezervave te vendburmit Kurbnesh”. ”. Archives of Albanian Geological Survey, Tirana.

KAMBERI, R. and BARDHOSHI, N., 1980: “Report of reserve calculation Munella deposit”. Archives of Albanian Geological Survey, Tirana.

KATI, P. and KOCI, M., 1980: “New data for sulphide mineralazitation composition of Gurthspac-Munelle-Munelle-Qafe Bari. In Albanian. Archives of Albanian Geological Survey, Tirana.

KOKONA, P.,1973: “Report of reserve calculation Qafe Bari deposit”. Archives of Albanian Geological Survey”, Tirana.

KOLNDREU , D. and SULEJMANI, LL. ,1984 “Report of reserve calcualtion, Sapci deposit”. Archives of Albanian Geological Survey, Tirana.

Lleshi N. and Leka, Gj.,1988: “Report on reserve calculation, Munella deposit”. Archives of Albanian Geological Survey, Tirana.

LLUBANI, B. and KODRA, A., 1973: “ Report of reserve calculation Gurthspac deposit”. Archives of Albanian Geological Survey, Tirana.

LLUBANI, B. and ZAGANJORI, B., 1984: “Report of reserve calculation Gurthspaci deposit”. Archives of Albanian Geological Survey, Tirana.

ROBERTSON, A.H.F. and XENOPHONTOS, C. ,1993: “ Development of concepts concerning the Troodos ophiolite and adjant units in Cyprus”. *In* Prichard, H. M., Alabaster T., Harris, N.B. and Neary, C.R (Eds), *Magamatic Processes and Plate Tectonics. Geol. Soc. Spec. Publ. London, **70**:85-120*

ROBERTSON , A.H.F. and SHALLO, M., 2000: “Mesozoic-Tertiary tectonic evolution of Albania in its regional Eastern Mediterranean context”, Tectonophysics, 2000, **316**, 197-254.

SHALLO, M., 1994: “Outline of the Albanian ophiolites”, “Ofiloiti”, 1994, **19**, 57-75

SHIMA, G. ,1973: “Report of reserve calcualtion, Sapci deposit”. Archives of Albanian Geological Survey, Tirana.

ZAÇAJ, M., 1987: Sulphide mineralizations of Perlati deposit and itssorroundings , Mirdita district (Disertacion).

ZOI, N. and KAMBERI, R., 1984: “Report of reserve calculation Munella deposit”. Archives of Albanian Geological Survey, Tirana.