Metallogenetic features of the lead-zinc and copper deposits in Iran

By J. G. HADITSCH*)

With 9 Figures

Zusammenfassung

Obwohl die Blei-Zink- und Kupfer-Lagerstätten des Iran in den vergangenen Jahren verstärkt untersucht wurden, blieben bis heute noch gewisse Fragen nach dem Zusammenhang dieser Mineralisationen untereinander und mit magmatischen Ereignissen unbeantwortet. Eine kritische Gegenüberstellung der betreffenden Vererzungen ergab

1. keine auffallende zeitliche Übereinstimmung der Pb-Zn- mit den Cu-Mineralisationen, besonders im Paläozoikum und in der unteren und mittleren Trias,
2. daß magmatische Gesteine oft nur die Erzträger, aber nicht die Erzspender darstellen,
3. daß, abgesehen von Metallisationen, die von magmatischen Ereignissen abgeleitet werden können, es verschiedentlich auch solche gibt, die keine aszendente Herkunft erkennen lassen, und
4. daß vielfach noch die Rolle der Paläokarstentwicklung für die Lagerstättenbildung unberücksichtigt blieb.

Bewußt wird in dieser Arbeit nicht auf den Zusammenhang der Mineralisationen mit der plattentektonischen Entwicklung eingegangen.

M. TARKIAN, M. LOTFI & A. BAUMANN (1984) were able to demonstrate that in the Central Lut region all magmatic events were connected with copper and, sometimes, also with lead-zinc mineralizations: The Jurassic magmatism with its intrusions of granites was followed by a disseminated Cu mineralization; the Laramidian uplift and magmatism (at the Upper Cretaceous/Paleocene boundary), by

*) Author's address: Univ.-Prof. Dr. Johann Georg HADITSCH, Mariatroster Straße 193, A-8043 Graz.

porphyry copper ores, and, consequently, the Pyreneean volcanism (at the Eocene/ Oligocene boundary) by vein-type mineralizations, copper in andesites, and lead and zinc in dacitic rocks.

The same multi-phase development, like in the Central Lut, can be demonstrated for the other metallogenic units of Iran. A comparison of the type of magmatism, the petrology of the country rocks and the metallisations show at least 8 different metallogenic phases, beginning with the Late Precambrian, and ending in the Early Miocene (Tab. 1). This sequence may give reasons for the assumption of a close connection between copper and lead-zinc mineralizations. It was the aim of this work to examine this presumption.

Table 1. Magmatic activity and related metallic occurrences in Iran (after D. Bazin & H. Hübner, 1969a, modified)

Probable age	Region	Type of Magmatism	Petrology	Metallisation
Early Miocene – Late Paleogene	Azerbayjan, Kashan, Kerman	Subvolcanic	Acid to intermediate	Cu (Pb, Zn, Mo, Au)
	Azerbayjan, Tarom, Kashan, Balutchestan	Plutonic	Acid to intermediate	Cu, Mo, W (Pb, Zn)
Paleogene, Upper Cretaceous	Wide spread	Volcano-sedimentary	Dacitic to basaltic, mainly andesitic	Cu, Pb, Zn, Mn, Ba (Ni, Co, Bi, U)
Upper Cretaceous	Zagros, Azerbayjan, Khorassan, Nain, Balutchestan	Submarine-volcanic to plutonic	Ophiolite, gabbro	Cr, Mn (Ni, Cu)
Late Early Cretaceous	Alborz, Golpaygan, Balutchestan	Volcanic	Basic extrusives	Pb, Zn (Cu)
Early Cretaceous – Late Jurassic	Azerbayjan, Hamadan, Central and SE-Iran	Plutonic, subvolcanic	Granodiorite, quartz porphyry, andesite porphyry	Cu, Pb, Zn, W, Mo
Infracambrian? (Taknar Form.)	Khorassan	Volcano-sedimentary	Mainly acid	Pb, Zn, Cu
Infracambrian (Rizu Series)	Central Iran	Volcano-sedimentary	Quartz porphyry, acid tuff	Pb, Zn (Cu)
Late Precambrian	Soltanieh, Golpaygan, Central Iran	Plutonic	Granite	Au

In Iran now more than 200 copper occurrences are known, most of them only being indications, which only partly have been investigated in a profound way. Nevertheless, the results encourage to give a brief synopsis.

The country rocks of the copper mineralizations show different ages (Fig. 1). While till up to the Triassic, and even in the Jurassic and Cretaceous sequences only a few metallisations are established, the most frequent and the most important mineralizations are developed in Tertiary rocks (Tab. 2). The occurrences in Triassic and older rocks are mainly bound to metamorphic formations, those in the Jurassic and Cretaceous to sedimentary and volcanic rocks, and the youngest deposits mainly to a volcanic environment. Drawing conclusions from this geological situation, it

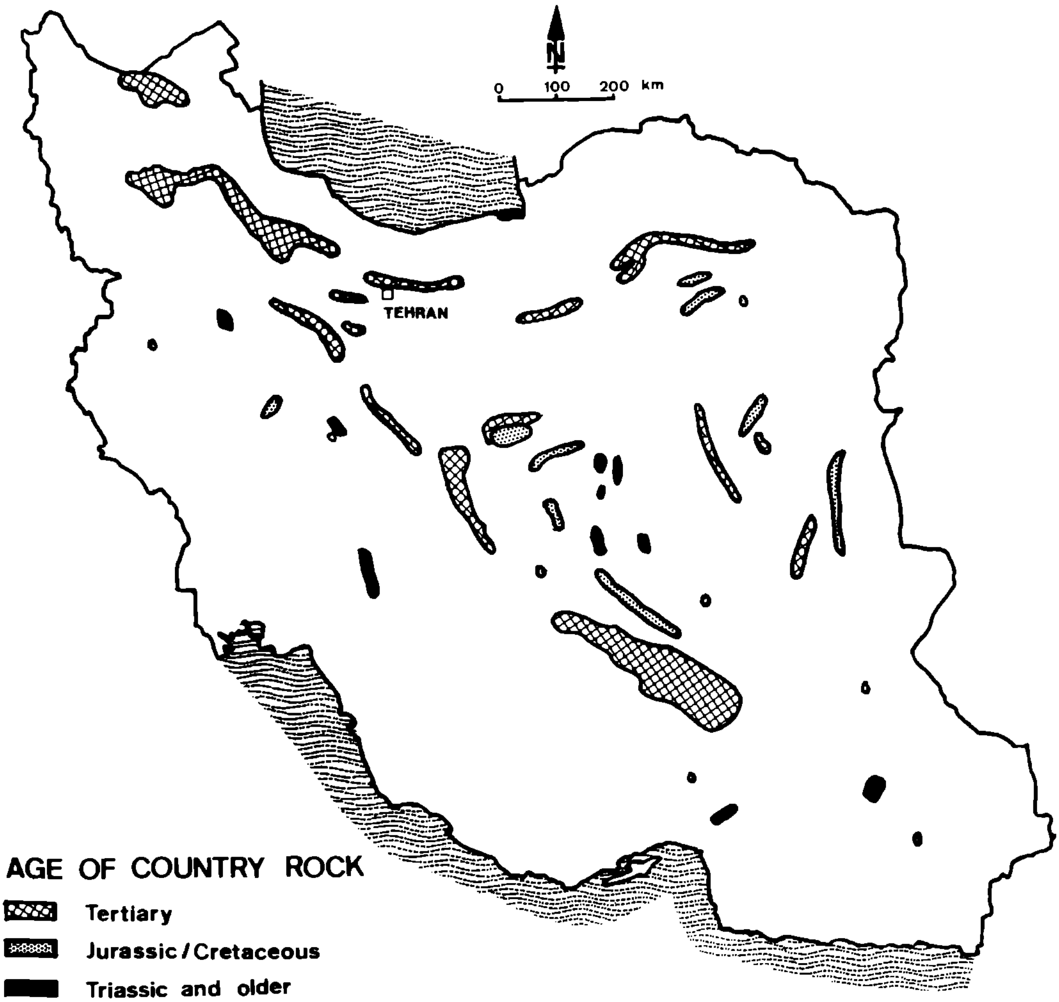

Fig. 1. Copper mineralizations in Iran: Age of the country-rocks

can be stated that all copper districts are showing a strong Tertiary volcanism, the different magmatic products being the main host-rocks for the mineralization. Only a few ore occurrences are connected with older country rocks (p. e., in the Anarak district Talkhe, Sebarz, Kan Mess, Chah Mille, Baqeroq).

Table 2. Copper deposits in Iran and the age of the host-rocks

Age	Size				Sum
	Large			Small	
Triassic and older		1	1		2
Jurassic			1	10	11
Tertiary	1	6	8	34	49

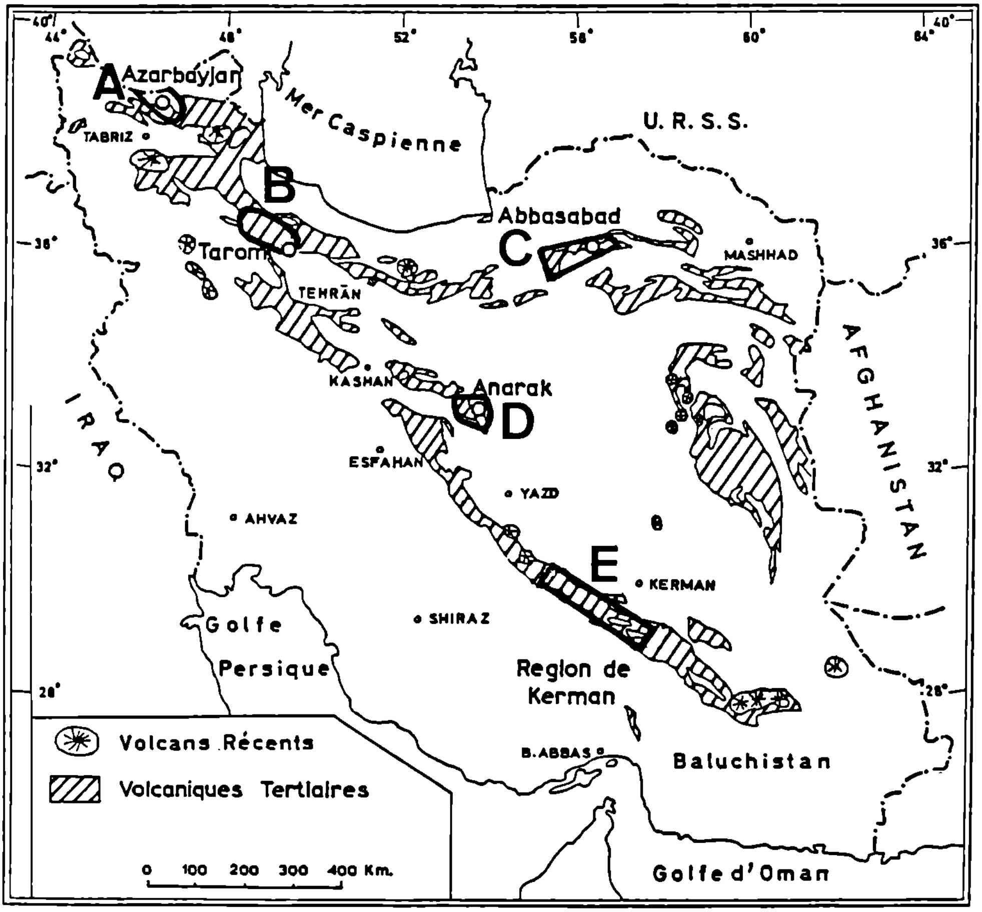

Fig. 2. Main copper districts in Iran (A–E) and their relation to Tertiary volcanic rocks (after D. Bazin & H. Hübner, 1969, modified).

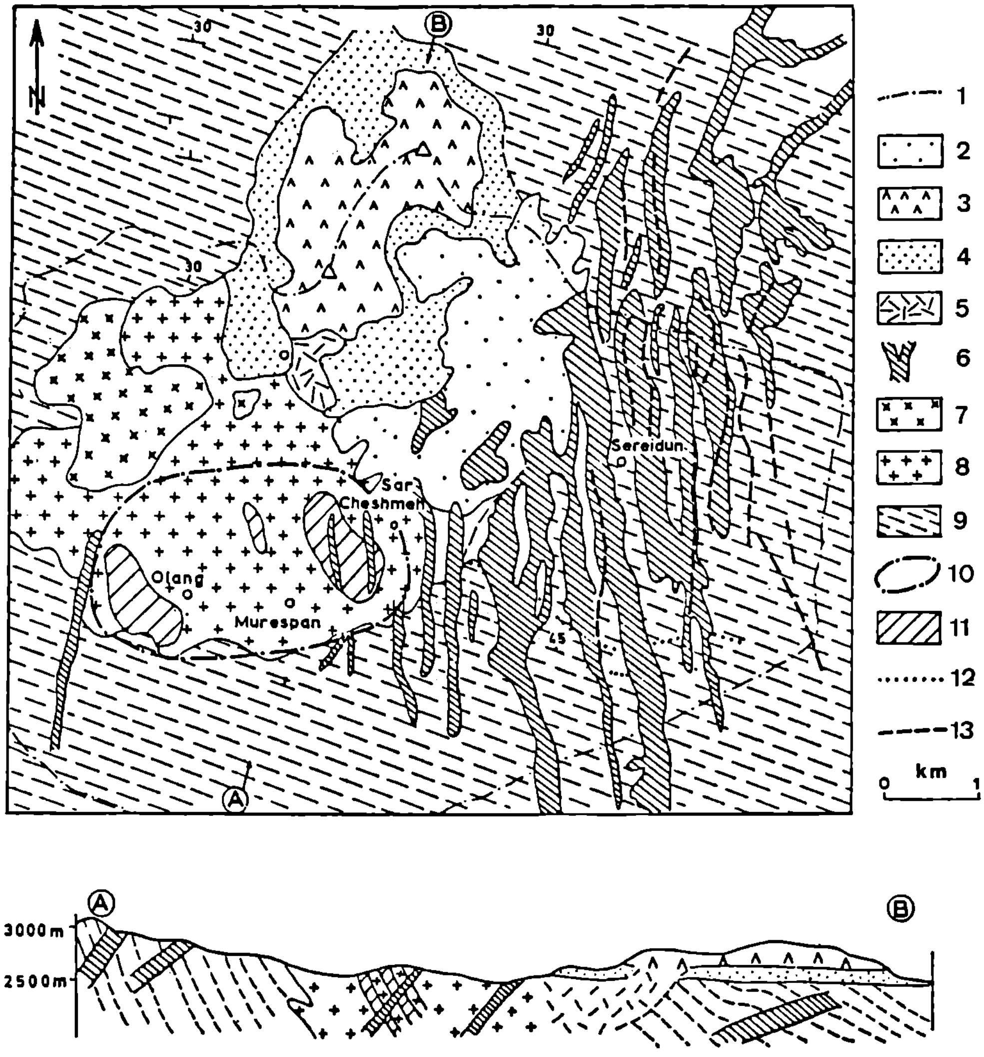

Fig. 3. Map and geological profile of the deposit Sar Cheshmeh. — 1 = Limit of the basin, 2 = Recent terrace with volcanic material, 3 = Dacitic lavas and ignimbrites, 4 = Volcanic conglomerates, cemented by ash tuff, 5 = Crystal tuffs, 6 = Dykes, 7 = Adamellite, 8 = Granodiorite, 9 = Paleogene lavas and pyroclastics, 10 = Boundary of primitive altered and mineralized intrusive, 11 = Enrichment area, 12 = Pyroclastic beds, 13 = Siliceous dykes (after D. BAZIN & H. HÜBNER, 1969)

Five different main copper districts can be distinguished easily (Fig. 2): Azerbayjan (A), Tarom (B), Abbasabad (C), Anarak (D), Kerman (E). The shape of these relatively small metallogenic areas is caused by very strong tectonic structures, which bound the Arabian and Euroasian plates and the Central Iranian fragments (A. A. NOWROOZI, 1976).

Among these five metallogenic units, the Kerman district is the most important one, with the greatest copper deposit of Iran, Sar Cheshmeh (D. BAZIN & H. HÜBNER, 1969 a, b). Here, Paleogene lavas, pyroclastics and sediments are cut by

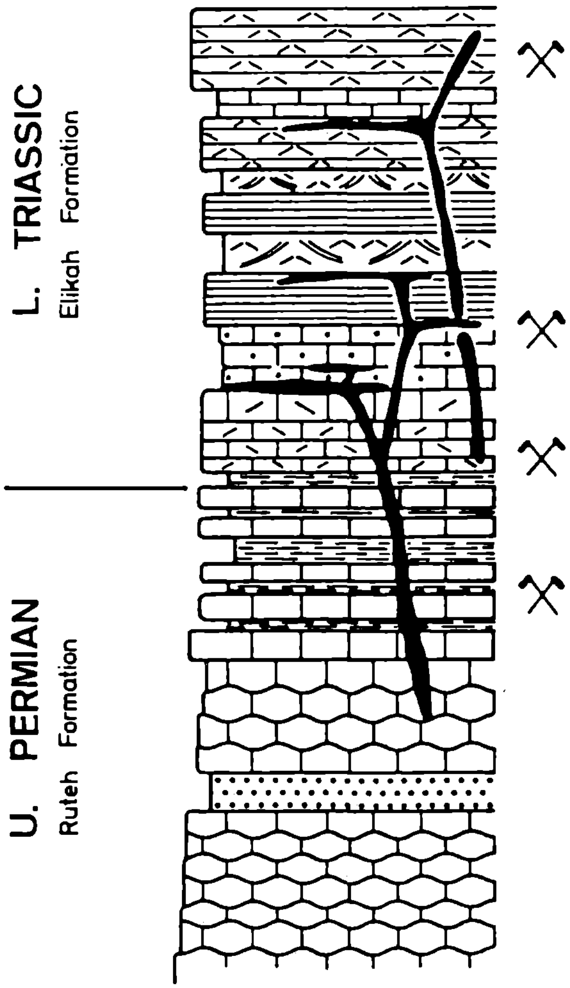

Fig. 4. Profile of Rochak near Rudbarak (Alborz) (after R. BRANDNER et al., 1981). – This figure demonstrates the stratigraphic position of the mineralization, which affected Upper Permian and Skythian strata. Some parts show stratiform mineralizations, but the discordant ones predominate. The synchronous dolomitization verifies the epigenetic character of the metallisation.

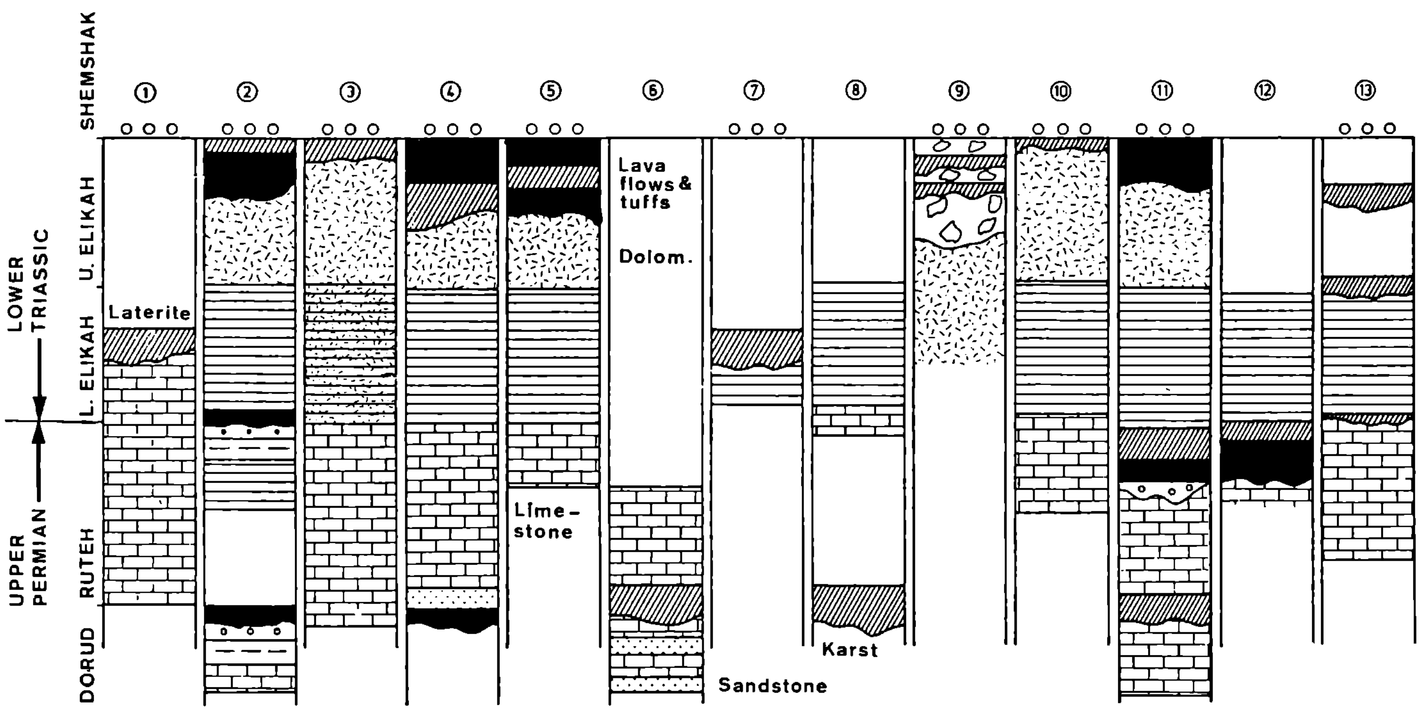

Fig. 5. Stratigraphic position of basaltic volcanic rocks and the karst development in the Alborz region (after R. BRANDNER et al., 1981, modified). – 1 = Rudbar, 2 = Gashnarud, 3 = Kelesther, 4 = Elikah, 5 = Kamerbun, 6 = Dizin, 7 = Gachare, 8 = Ruteh, 9 = Noor Valley, 10 = Mangol, 11 = Arruh, 12 = Gaduk, 13 = Goshnavi. – Ba-F-Cu deposits are bound to the karst and the subaeric basalt volcanism. At the different localities volcanism and karstification and, consequently, the mineralizations, show different stratigraphic positions.

Neogene subvolcanic intrusions (dykes, sills and stocks of a porphyritic granodiorite). The copper mineralization occurs mainly in the form of disseminations around altered stocks and within these bodies, and as veins, stockworks and impregnations in the surrounding lavas and pyroclastic rocks (Fig. 3).

Also the less important deposits are bound to Tertiary magmatic rocks: Sungun and Mazraeh (Karadagh) being skarn mineralizations, and Zahbad, Meskani, Talmessi and Chahar Gonbad such of vein-type. Only the stratiform deposits of Taknar are situated in Precambrian green schists (B. RAZZAGHMANESH, 1968).

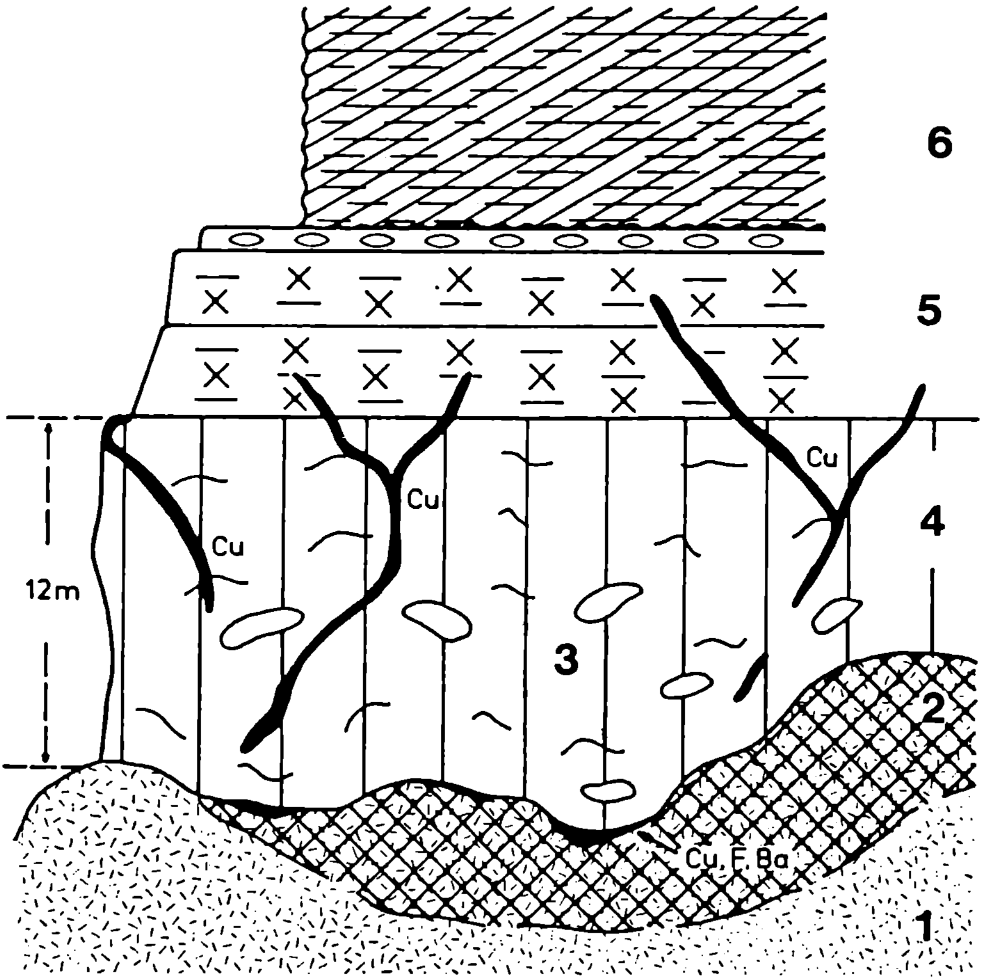

Fig. 6. Profile of Kamerbun (Alborz) (after R. BRANDNER et al., 1981). – 1 = Triassic dolomitized limestone, 2 = silicified beds, 3 = Laterite, 4 = Laterite with mobilized chalcopyrite, 5 = Crystal tuff, 6 = Slates (Shemshak Formation). The chalcopyrite veinlets originate from the small copper content of the laterite.

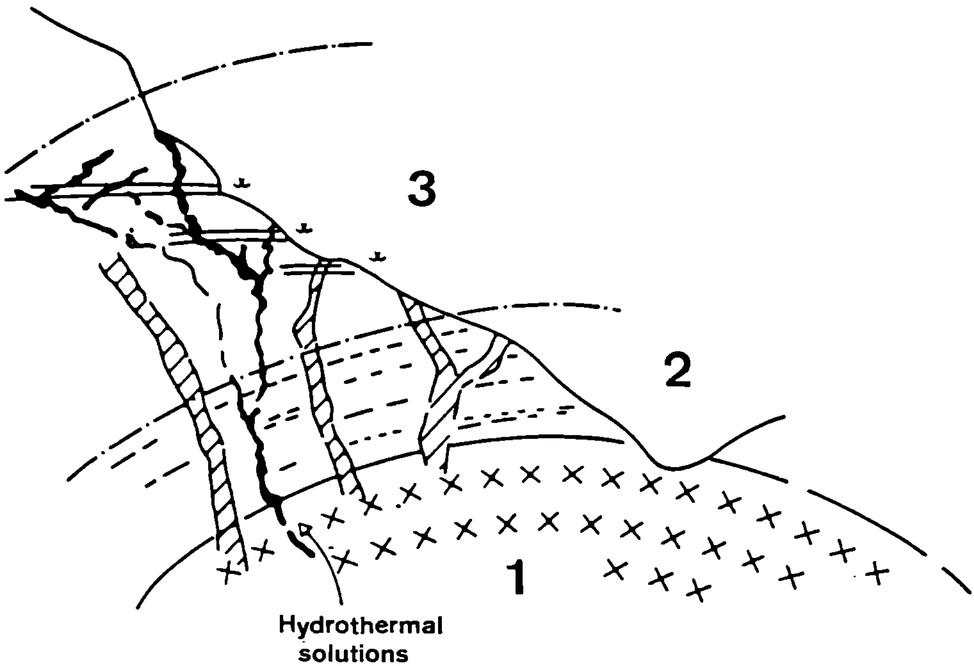

Fig. 7. Guret Mine (after R. BRANDNER et al., 1981). – 1 = Granite, 2 = Inner zone of contact metamorphosis (with hornblende, garnet, epidote, magnetite), 3 = Outer zone of contact metamorphosis. – Limestones and marls were metamorphosed by a Mesozoic granite. Aplitic, granodioritic and dioritic dykes cut the metamorphosed rocks. The chalcopyrite-galena-sphalerite mineralization is younger than the dykes, and was formed by hydrothermal solutions.

Among the smaller deposits most of those, which occur in Jurassic and Cretaceous rocks, have a sedimentary origin—with one exception: Dahaneh Siah—, while those of Tertiary age have magmatic, mostly volcanic country rocks. Also the Upper Cambrian Khanegah (Kuh-e-Dena) deposit in the Zagros range has limestone beds as host rocks.

Summarizing, the fact can be stressed, that there exists a remarkable difference between the metallisations in Paleozoic and Mesozoic rocks and those which affected Tertiary rocks: Nearly all of the mineralizations in the older rocks are connected with sedimentary rocks, and all in the Tertiary with magmatic ones.

The connection with sedimentary rocks does not necessarily imply that in any case the related ore deposits are of syngenetic origin, even if these mineralizations show stratiform features. This can be demonstrated easily in the section of Rochak in the Alborz chain (Fig. 4).

The extrusives may also have covered a karstic landscape; the karst phenomena too, can be of different ages (Upper Permian, and Lower Triassic, resp.; Fig. 5). Sometimes the uppermost parts of the Upper Permian paleo-karst are characterized by iron-rich carbonates, like ankerite, sideroplesite and siderite, and a weak copper mineralization, which later on could have been mobilized on some places; this, for instance, can be observed, at Kamerbun, where the karst is developed in Triassic limestones, associated with an intensive silicification, a lateritization and a Cu-F-Ba mineralization, followed by a postgenetic copper mobilization, evolved in the laterites (Fig. 6). The basic volcanic rocks, which at Kamerbun were affected by the lateritization, most probably have a lower Jurassic age, like in Elikah, where the Liassic age is proven.

It is not very often possible to prove the magmatic origin of the ore-bearing solutions in such a clear way like at the Guret Mine, near Kelardasht, in a series of limestones, marls and cherty shales, the age of these sediments most probably being Carboniferous. In Mesozoic times this series was affected by a granite, thus forming two zones of contact-metamorphism. Later, aplites, and granodiorite and diorite dykes crossed the metamorphic zones, and hydrothermal solutions had as a result Pb-Zn-Cu ores (Fig. 7).

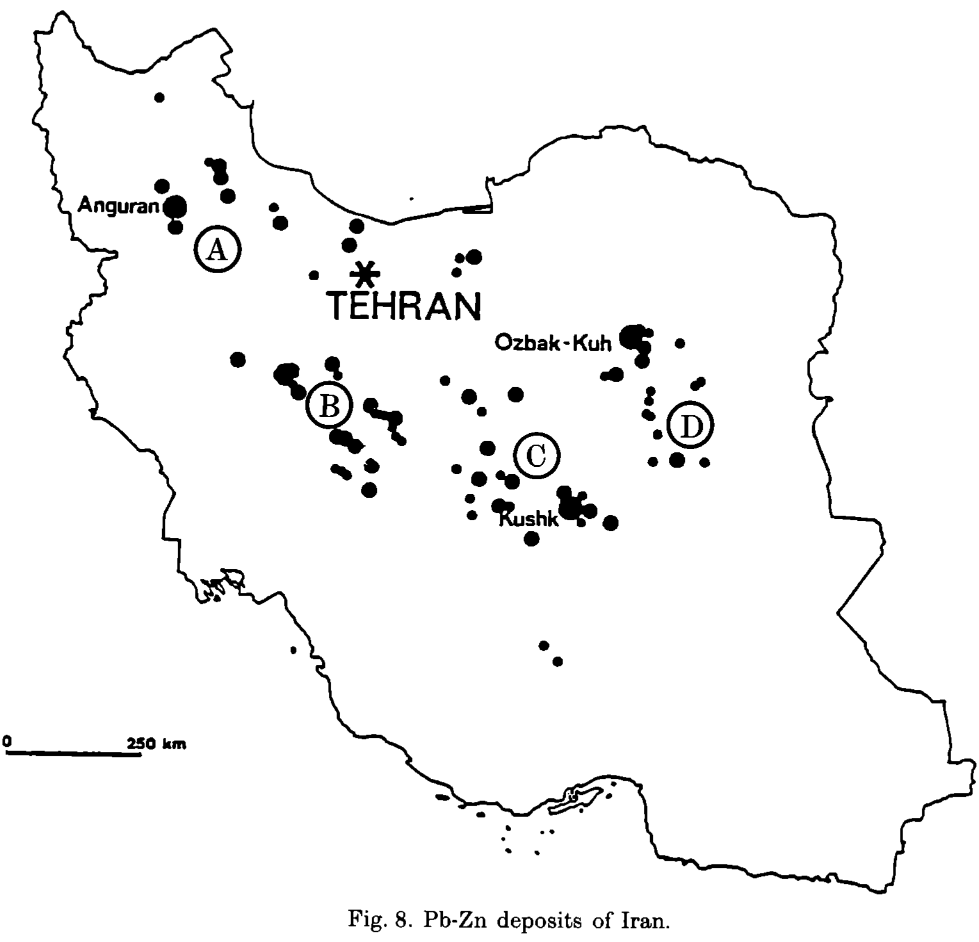

Fig. 8. Pb-Zn deposits of Iran.

The Iranian Pb-Zn deposits are concentrated mainly in the ranges, which are bound with the Great Salt Desert (Kavir). Four different regions can be distinguished (P. Bariand et al., 1965, L. Burnol, 1968):

1. Azerbayjan and the Alborz chain (Fig. 8, A),
2. the region of Esfahan and Arak (B),
3. the area of Anarak and Yazd (C),
4. the eastern ranges of the Kavir between Ferdows and Tabas (D).

In the first area (A) the most important Pb-Zn deposit of Iran is situated (Anguran), partly showing stratiform and partly karstiform features. Between Anguran and the deposits in the Alborz chain volcanic rocks of Tertiary age (Eocene), near Rasht, show vein mineralizations with a remarkable proportion of copper and gold (p. e., Zahbad, Ghare Djangal).

In the central part of Iran (B) some well-known mineralizations are situated around Esfahan and some more to the NW, i. e. between Golpaygan and Arak (p. e., Lakan, Hosseinabad).

In the region of Anarak and Yazd (C) most varying deposits are developed, namely Kushk, Nakhlak, Merjard, and Zirakan.

Of all the metallisations in the chain east of the Kavir (D), the deposit of Ozbak-Kuh is the most interesting one.

For a lot of these deposits epigenetic (i. e. hydrothermal-metasomatic) events were postulated. Meanwhile for some of the most important mineralizations, indications of an originally syngenetic sedimentary protore formation, could be found. These originally stratiform mineralizations were overwhelmed epigenetically by multistage hydrothermal mobilizations (p. e., J. G. Haditsch, 1982, 1984). By this, e. g., the Pb-Zn deposits in Upper Paleozoic and Mesozoic strata in the east of Iran could be defined as inherited or traced ore deposits ("Vererbungslagerstätten" and "durchgepauste Lagerstätten", resp.).

L. Burnol (1968) distinguished different types of Pb-Zn deposits, according to their ore minerals, the temperature of their formation and the type and the amount of the gangue:

Type I: Deposits with sphalerite, galena, pyrite, chalcopyrite and minerals of elevated formation temperature ("mesothermal" after W. Lindgren). These deposits show veins with quartz ± baryte ± dolomite as gangue minerals, some arsenopyrite and pyrrhotine; the latter mineral and chalcopyrite may also occur in the form of segregated grains in the blende. The deposits were formed during different stages, which demonstrate a normal mineral succession, according to the successive decrease of temperature, and an alteration of the country rock.

Type II: Deposits with sphalerite, galena, pyrite, chalcopyrite, without minerals of elevated formation temperature. – Sub-type II a: Mesothermal deposits, with a normal mineral succession, deposited in one phase, and with a remarkable amount of various gangue minerals. Quartz is the main gangue, some carbonate minerals (siderite, dolomite, calcite) may also occur. The host-rocks were altered with different intensities. – Sub-type II b: Volcano-sedimentary stratiform deposits, with sphalerite (schalenblende), pyrite (melnikovite-pyrite), galena ± chalcopyrite, and with only gangue accessories.

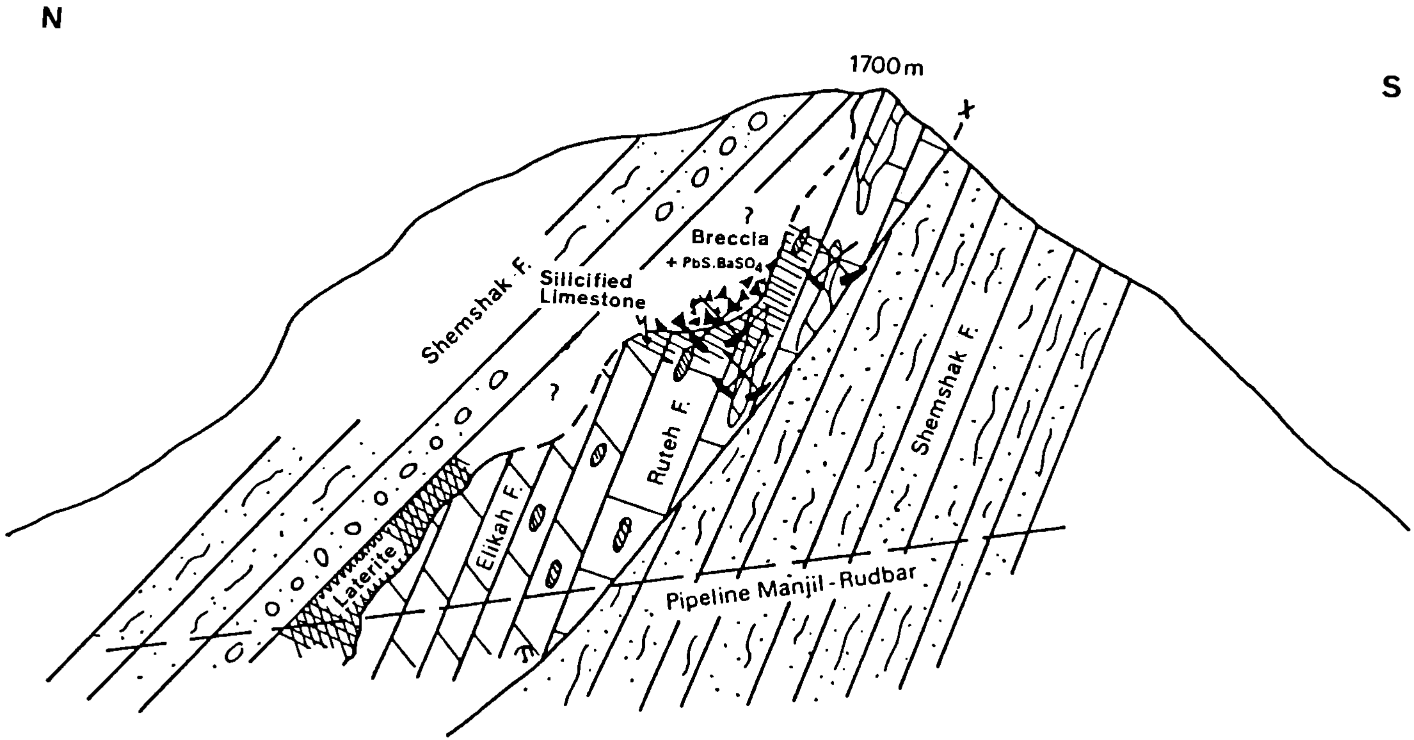

Fig. 9. Himmelmine (Manjil) (after R. BRANDNER et al., 1981). – Laterite, in sedimentary contact with Triassic dolomites. Limestones of the Ruteh Formation (Permian) and the hanging breccia were partly, resp. totally silicified, and mineralized by galena and baryte. The silicification and ore mineralization originate from solutions, which were transported by a river system, and precipitated at the water table.

Type III: Pb-Zn deposits, with either dominating galena or sphalerite, and few or even missing gangue minerals.

Type IV: Epigenetic galena deposits, partly stratiform, and sometimes also bearing sphalerite, and with quartz, fluorine, baryte as gangue minerals. – Sub-type IV a: Quartz is the main gangue mineral, accompanied by more or less baryte and calcite. – Sub-type IV b: With baryte or fluorine, one of these gangue minerals dominating, often together with some quartz and calcite. – Sub-type IV c: The gangue is mainly baryte, sometimes associated with some quartz, calcite, and fluorine.

According to this classification, the Type III (with the mineralizations of Anguran, Kelardasht, Ozbak-Kuh, Zirakan, Nakhlak, Lakan I, Shah-Kuh and Anjireh-Tiran) is by far the dominating among the Iranian deposits, the relating mineralizations only rarely being stratiform, but in any case of epigenetic origin.

The Sub-types II a and II b are represented by the interesting mineralizations of Zahbad and Seh Changi, and Kushk, respectively.

The hypothermal deposits (Type I) with, p. e., the mineralization of Merjard, are of less importance, and the metallisations of the remaining Sub-types IVa, b, c, represented by p. e., Lakan II, Sar-e-siah, Ormodeh, Mehdiabad, are unimportant.

There is no doubt about the existence of sedimentary Pb-Zn mineralizations, as, e. g., the deposits of Kushk and Zirakan in the Infracambrian sequence of the Saghand-Bafq area. Only a few of these deposits are of economic interest. Many other deposits are strata-bound, or even stratiform, like, e. g., Ozbak-Kuh, Lakan II, Anjireh, but in these cases the original sedimentary metallisation is of no economic value in contrast to the related epigenetic vein mineralizations. In these cases, mobilizations generated economic Pb-Zn concentrations, this mainly by hydrothermal alteration (e. g., Ozbak-Kuh) or by processes in a karstic environment (Anguran, Manjil, etc.).

The most important Iranian Pb-Zn deposit, Anguran, shows at its base a stratiform sulphide mineralization covering mica schists. It is not yet proven, that this contact is caused by an overthrust fault. The dolomitic limestones in the hanging wall of the above-mentioned and less important sulphide mineralization were affected by a strong karstification. The karst cavities were filled epigenetically by Pb and Zn oxide minerals, as, e. g., cerussite, anglesite, smithsonite, hydrozincite, willemite, hemimorphite. Only this high-graded mineralization actually is worked in an open pit.

At Manjil, Lower Triassic dolomites of the Elikah Formation and limestones of the Permian Ruteh Formation show an Upper Triassic paleo-karst development, with a silicification and a mineralization, mainly consisting of galena and baryte (Fig. 9).

A comparison with the copper mineralizations only partly shows a coincidence, and not in the case of the most important Pb-Zn deposits, namely Anguran, Ozbak-Kuh and Kushk.

H. Förster (1974) tried to give a first synopsis of the Iranian deposits, based on plate-tectonics. Since then, it became possible to give another review, related to the metallogenic evolution.

Table 3. Metallogenic evolution of the Pb-Zn and Cu deposits in Iran

METALLOGENIC EPOCHS	SUB-EPOCHS	EXAMPLES	FORM	Cu	Pb-Zn
Upper Cretaceous – Pliocene	Eocene – Pliocene	Sar Cheshmeh	O /	▮	
		Kuh-e-Panj	O /	▮	
		Merjard	/	▮	
		Meskani	/ .	▮	
		Talmessi	/ .	▮	
		Qaleh Zari	/	▮	
		Dahaneh Siah	O / =	▮	
		Abbasabad	/	▮	
		Neshapour	/	▮	
		Seh Changi	/	▮	
		Kuh-e-Garmab	/		▮
		Nakhlak	/ =		▮
		Zahbad	/		▮
	U. Cret. – Paleocene	Nohdeh	O /	▮	
		Garmab	=		▮
Jurassic – Lower Cretaceous	Lower Cretaceous	Natanz	/		▮
		Akhlamad	/ =		▮
		Boghestan	/ =		▮
		Darreh zanjir	=		▮
		Chek Chekou	=		▮
		Mehdiabad	=		▮
	Jurassic	Sorkhkuh	O	▮	
Permian – Upper Triassic	Late Triassic	Manjil (Himmelmine)	=		▮
		Alborz	/ =	▮	
	L/M Triassic	Ahmadabad	/ =		▮
		Kuh-e-Sormeh	=		▮
	Permian	Anjireh	/ =		▮
		Harzabil (N)	=		▮
Upper Devonian		Ozbak-Kuh	/ =		▮
		Galeh	/		▮
Infracambrian		Koshami	=	▮	
		Narigan	=	▮	
		Kushk	=		▮
		Zirakan	=		▮

/ Vein mineralization.

O Porphyry copper.

. Impregnation.

= Stratiform mineralization (Karst mineralizations included).

Concerning the Pb-Zn and Cu mineralizations, now in Iran five metallogenic epochs are distinguishable; three of them also can be subdivided into sub-epochs (Tab. 3. To be on the safe side, in this figure only verified examples are given).

The metallogenic evolution from the Infracambrian to the Tertiary shows a distinct development from stratiform mineralizations and impregnations to such of vein-type.

A comparison of Tab. 1 with Tab. 3 demonstrates that

1. there is no strong temporal coherence between the Pb-Zn and Cu mineralizations, especially in the Paleozoic, and in the Lower and Middle Triassic;

2. magmatites often are only the country-rocks of the mineralizations, and were not the donors of the ore-forming solutions;

3. there exist not only metallisations, which have their origin in magmatic events, but also mineralizations without any visible connection with a magmatic source. For these mineralizations a formation by descending solutions is to assume with good reasons;

4. in many cases the important role of paleo-karst for the genesis of ore concentrations has been undervalued or even neglected.

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