The Pb-Zn-Deposits of Keban (SE-Taurus Mountains) and its Position in the Aegean-Tauriden Metallogenetic Province

By ERICH SCHROLL*) and HIDIR CAGLAYAN**)

With 9 Figures

Zusammenfassung

Der Vergleich der geochemischen Parameter, also vorwiegend der Verhältnisse der Spurenelemente und der Isotopen, zeugt für die Verwandtschaft der Pb-Zn-Lagerstätten von Laurion und von Keban und bestätigt damit die von DE LAUNAY (1911) und W. E. PETRASCHECK (1955) auf lagerstättengeologischer Basis getroffene Zuweisung zu einer tertiären, magmatogenen ägäisch-tauridischen Erzprovinz.

1. Introduction

It is one of the objectives of this paper to test the application of geochemical characterization (geochemometry***)) of lead, zinc ore mineralizations hosted in carbonatic rocks. The principles of geochemical characterization are presented by SCHROLL (1979, in press). The geological observations, the petrological and mineralogical investigations, including the geochemical data of the ore mineralization of Keban are published in more detail by CAGLAYAN (1984). Another point is the contribution to a better knowledge of the lead-zinc bearing ore mineralization of the Aegean-Tauriden metallogenetic province.

2. Geographical and geological situation

The ore occurrences of Keban are situated in the South-Eastern Taurus Mountains in the vicinity of the town Elazig in Turkey. The ore mineralizations are bound

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*) Geotechnisches Institut der BVFA-Arsenal, A-1031 Wien, POB 8.
**) University of Ankara, Department of Geology, Tandógan, Ankara, Turkey.
***) This technical term is used in this paper for the first time.

mainly on a Permian carbonatic rock series like other ore deposits of the Taurus Mountains, such as Bolkardag or Karalar, which are known as strata-bound ore mineralizations (VACHE, 1966, LAZNICKA, 1981).

The carbonatic rock series consists of Permocarboniferous limestones and marbles, Permian limestones and calcareous schists, Triassic calcareous phyllites and meta-conglomerates, followed by Jurassic sedimentary rocks and Quaternary sediments. Permean and Triassic rocks are weakly metamorphosed by tectonic events in Jurassic time. The Paleozoic and Triassic strata are penetrated by subvulcanic syenitic intrusions and trachytic effusives, partly forming skarn mineralizations within the carbonatic rocks.

Fig. 1 shows the localization in the metallogenetic province and the geological sketch of the area of Keban.

3. Ore mineralizations

The geological sketch Fig. 1 shows three localities of mining activities:

1. Nalliziyaret, named shortly Keban in this paper. The skarn mineralization caused by the intrusion of syenit-porphyr is situated in the valley of the river Firat.

The mineralizations bear scheelite, fluorite, pyrite, galena, sphalerite and chalcopyrite; diopside, actinolite, vesuvian, epidote, mica, titanite etc.

2. Bamas, in the North of Keban, is a skarn type too, characterized by a dominant mineralization of molybdenite, fluorite and chalkopyrite.

3. Firat-Derebaca, named shortly Firat in the South of Keban. This is an intensive ore mineralization of galena, sphalerite, chalcopyrite and pyrite. These ores are the object of the present mining activity. However scheelite and molybdenite is not found.

4. Magmatism

The syenitic and trachytic rocks are contemporary with granodioritic intrusions in this area. The alcali rocks are rich in K 5—10% (K/Rb ~ 500), Ba 0,3%, Pb 30 ppm, and Th 67 ppm (Th/U ~ 10), but relatively poor in Rare Earth elements and zirconium.

5. Preceding genetic conceptions

Most geologists who visited the ore deposits of Keban, like KOVENKO (1938), MAUCHER (1938), PETRASCHECK (1955, 1960), OELSNER (1958, 1960) emphasized an epigenetic origin.

ZUSSERMANN (1969) only decided in favour of stratiform deposition.

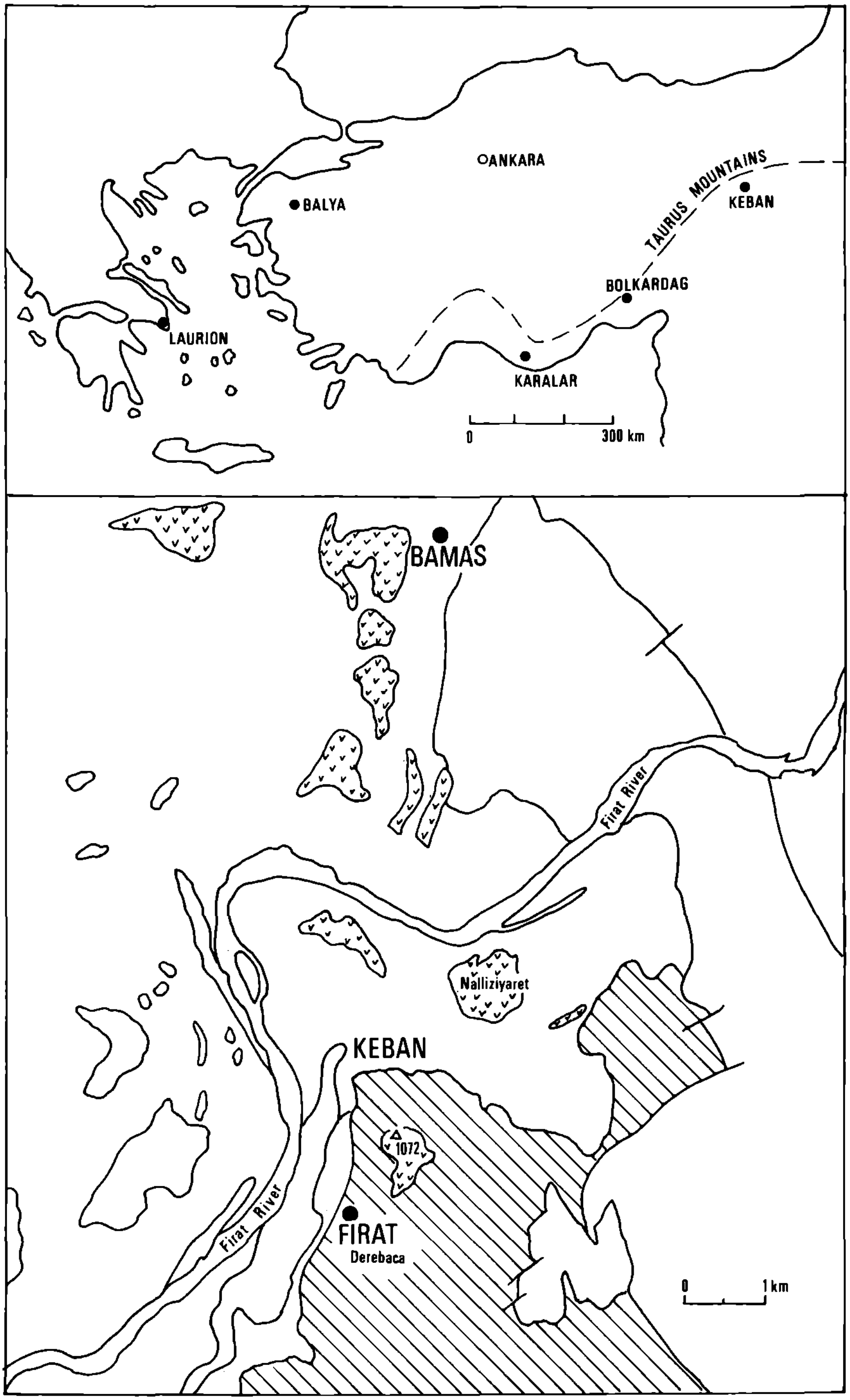

Fig. 1. Sketches of the localization of the Keban ore deposits in the Aegean-Tauridean metallogenetic province and the geological environment of the ore mineralizations. The area of Triassic rocks is hatched and the occurrences of trachytes and syenitic rocks are indicated. The Permian is not marked. The marls are separated by border lines. The younger covering sediments are neglected.

6. Geochemometric investigations

A minimum of numbers of samples, but non less than three for each mineral species of each locality, has been selected. The specific sampling based on field work and mineralogical observations. The objects were mainly the carbonatic wall rocks, calcites, fluorites, pyrites, sphalerites and galenas.

Chemical and isotopic data are necessary for geochemometric work: trace- and minor element distribution in ore minerals and gangue minerals, and the isotopic composition of carbon, oxygen, sulphur and lead.

6.1. Chemical data

Locality	Pb	Zn	Cu	Ag	
Keban	3,5%	4,0%	1,4%	20 g/t	Fe > Pb + Zn
Firat	6,0%	4,2%	1,0%	20 g/t	Fe < Pb + Zn

Minor and trace element distribution. Some selected examples of the distribution of Sb/Bi in galena, Fe/Cu in sphalerite of Ni/Co in pyrite (Ni/Co) and of Tb/La in fluorite (Tb/La) are represented in Figs. 2–5.

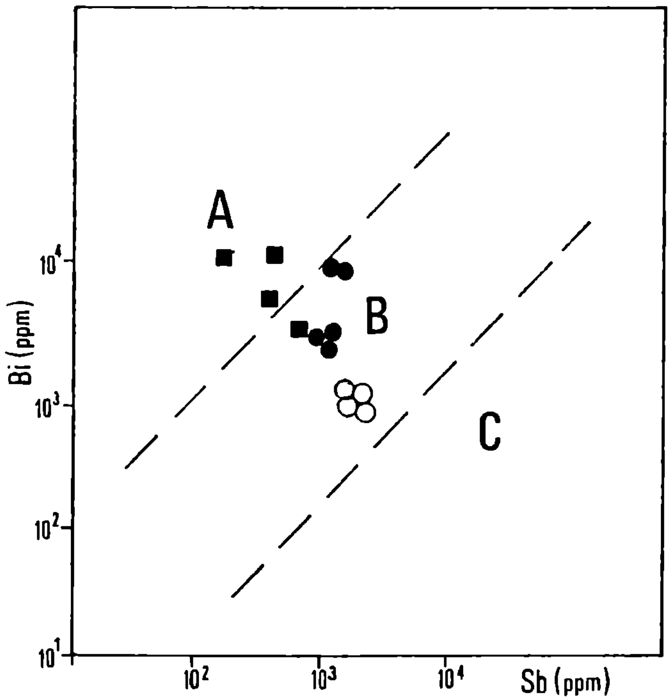

Fig. 2. Sb/Bi-rations of galenas. Ranges of deposition temperatures after MALAKHOV (1969): A Bamas (200–300° C), B Keban-Nalliziyaret 140–220° C, C Firat (100–150° C). Black squares: Bamas, black points: Nalliziyaret and open circless: Derebca-Firat.

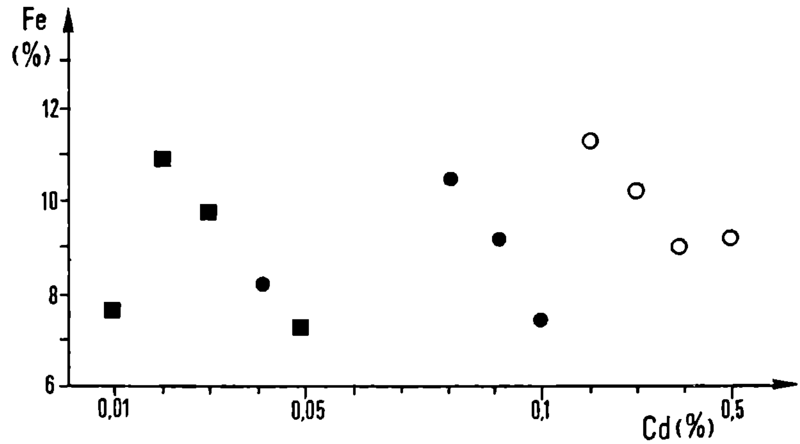

Fig. 3. Fe/Cd-Variation diagramm of sphalerites. The cadmium concentrations decrease from Bamas to Firat following the formation temperature.

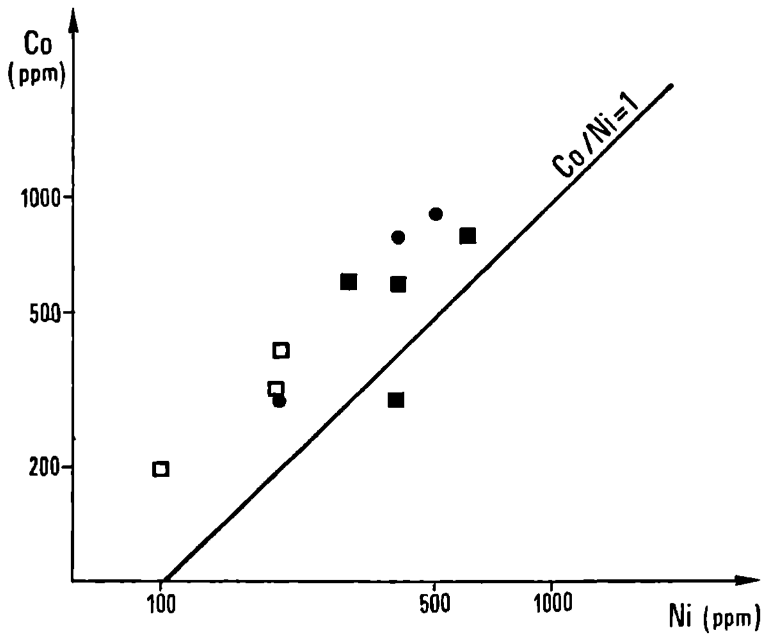

Fig. 4. Ni/Co-rations of phyrites. Co dominates in all samples except one. The absolute concentrations of Ni and Co are lowest in Firat.

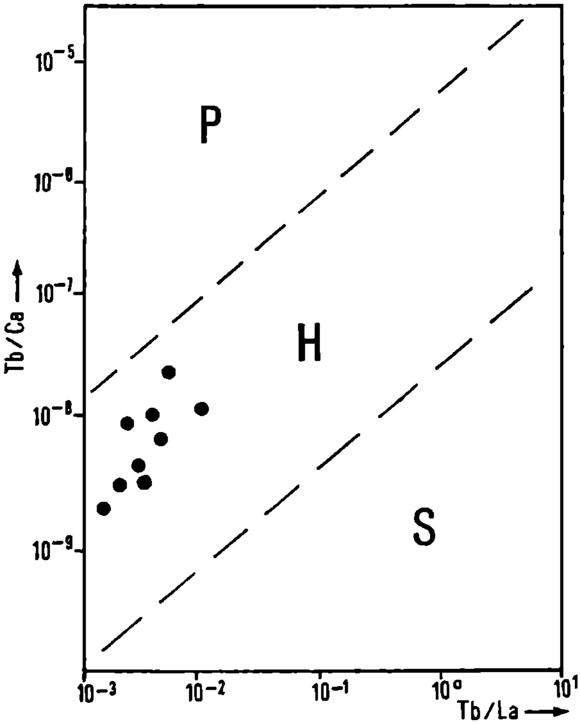

Fig. 5. The Tb/La–Tb/Ca-diagram after MÖLLER et al. (1977) suggests the hydrothermal formation. Remobilization processes can't be excluded. – P = pegmatitic or pneumatolytic; H = hydrothermal; S = sedimentary.

The sphalerites contain relatively high concentrations of Fe (up to 10%), Mn (up to 1%), low contents of Cd (0,02–0,2%) and other rare metals.

6.2. Isotopical data

6.2.1. Isotopes of carbon and oxygen of carbonates

The hydrothermal-metasomatic calcites of the ore mineralization are significantly different from the limestones. The isotopic composition shows large differences on the sharp bounderies between the ore calcite and the wall rocks (Δ $\delta^{13}C$ 3‰, Δ $\delta^{18}O$ 7‰).

The calcites of the ore mineralization fall within the hydrothermal field of the $\delta^{13}C/\delta^{18}$ O-diagram (Fig. 6).

6.2.2. Isotopes of sulphur

Galenas, sphalerites and pyrites show $\delta^{34}S$ values near zero, but with a slight tendency to light sulphur (–0,8 up to –4,4‰). The lightest sulphur is found in the

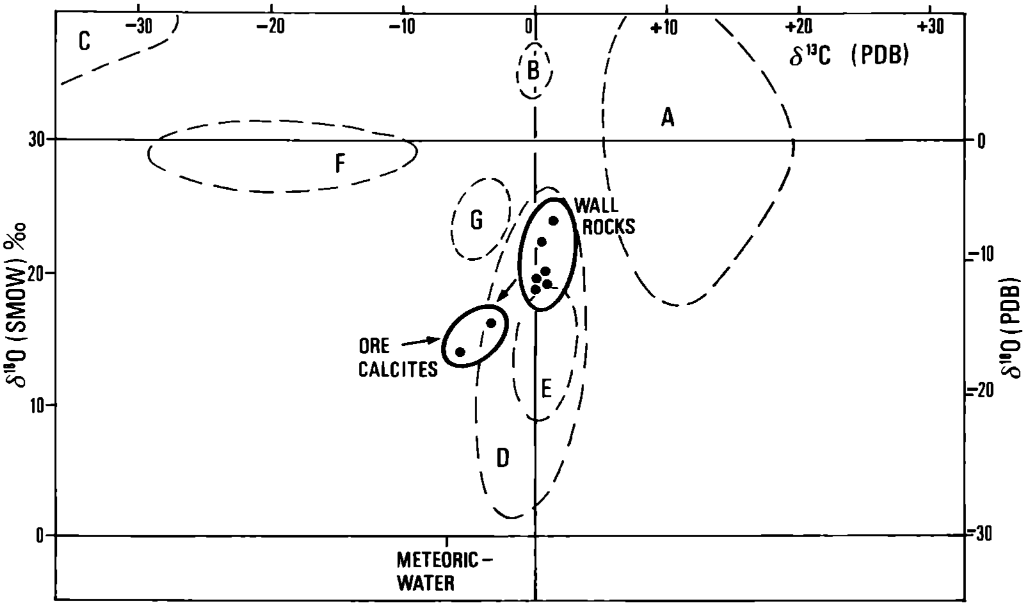

Fig. 6. Carbon and oxygen isotope composition of carbonatic wall rocks and calcites of the mineralization. Fields of carbonatic sediments after HUDSON (1977). Dotted field after HUDSON (1977): A = heavy carbon sediment; B = deep water limestones; C = methan derived cements; D = late cements; E = marine limestones; F = early diagenetic concretions; G = fresh water limestones.

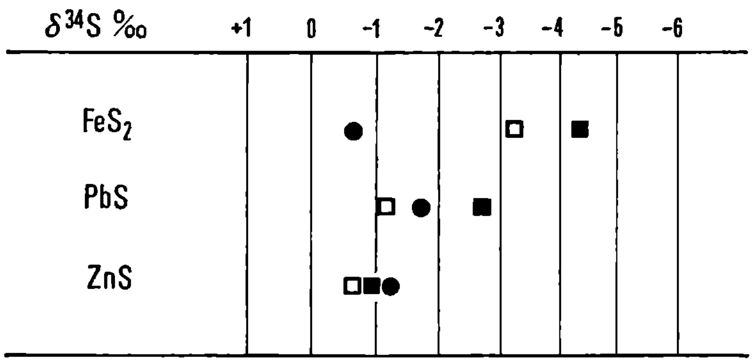

Fig. 7. Sulphur isotope composition of sphalerites, galenas and pyrites.

occurrences of Bamas and Firat. If coexistent mineral pairs being in equilibrium (after OHMOTO, 1972), the differences of $\delta^{34}S$ values should correspond to high temperature ranges.

The sphalerites are showing the heaviest sulphur, the pyrites, except samples of Keban the lightest (Fig. 7).

6.2.3. Lead isotope

The mass spectrometric investigation of two samples of galena and feldspar from one of the trachyte rock samples gives the following results:

	$^{206}Pb/^{204}Pb$	$^{207}Pb/^{204}Pb$	$^{208}Pb/^{204}Pb$
Galena, Firat	19.185 ± 015	15.684 ± 015	39.180 ± 0.030
Galena, Keban	19.146 ± 003	15.695 ± 002	40.438 ± 0.010
Feldspar, Firat	21.868 ± 005	15.807 ± 005	40.438 ± 0.010

The leads are average lead of the Earth crust mixed with a component of younger lead of the upper crust. The leads of ore and of rock are radiogenic (Fig. 8). If the line drawn through the points of the data for ore and rock would be identical with an isochron, a model age could be estimated approximately with 0 ± 100 Mio years corresponding to the young age of the magmatic rocks. The ore lead is slightly thorogenic, so that the acceptance of consanguinity with the thorium-rich alcali rocks seems to be probabel.

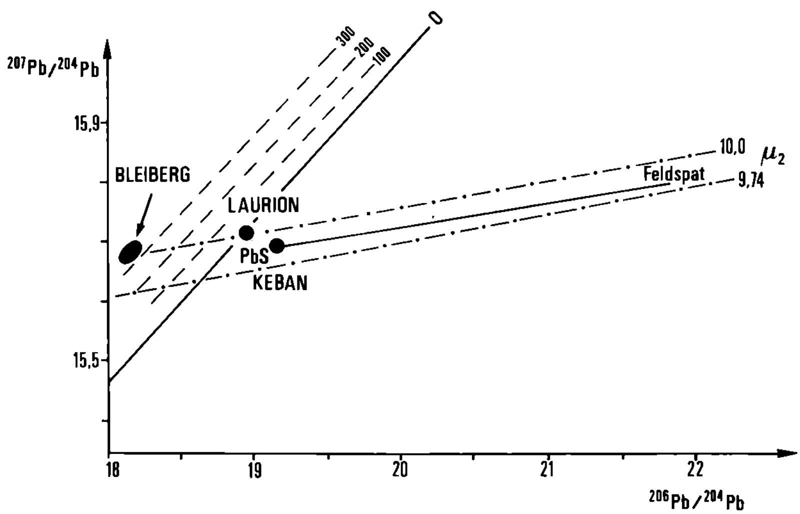

Fig. 8. Lead isotope diagram (lead-evolution model after STACEY/KRAMERS, 1975) showing the radiogenic character of ore lead and rock lead.

6.3. Geochemical parameters

The geochemical data supply strong arguments for epigenetic genesis, caused by high-temperature leaching and hydrothermal deposition. The chemistry of the ore minerals and lead isotopes of the largest metal concentration Firat is identical with the other ore occurrences. The temperature of the deposition of the ore solutions in Firat should be lower than in Keban and Bamas, but around 200° C or more. The negativ $\delta^{13}C$-value of the calcites speaks for endogenic origin.

However it remains still an open question, whether ore mineralizations are partly the product of remobilization processes or not.

7. Position in the Aegean-Tauridean metallogenetic province

The visual comparison of ore samples of Keban (Turkey) and Laurion (Greece) suggests similarities. There is a correspondance of the geochemistry of the sphalerites. SCHROLL (1954) reported analyses of sphalerites of Laurion: Fe 3—10%, Mn up to 1%, Co 0,05—0,3%, Ga up to 10 ppm.

The leads of Laurion showing young model ages are perhaps weakly radiogenic, but are not thorogenic after the data of GALE (1978). The μ_2-values around 10 are comparable with leads derived from the African platform.

A further geochemical study could be of interest. However the Pb-Zn-Ba-mineralizations of the type Bolkardag are the key to the problem. A regional study of lead isotopes is emphazised. Some published values of lead isotopes are plotted in the last Fig. 9.

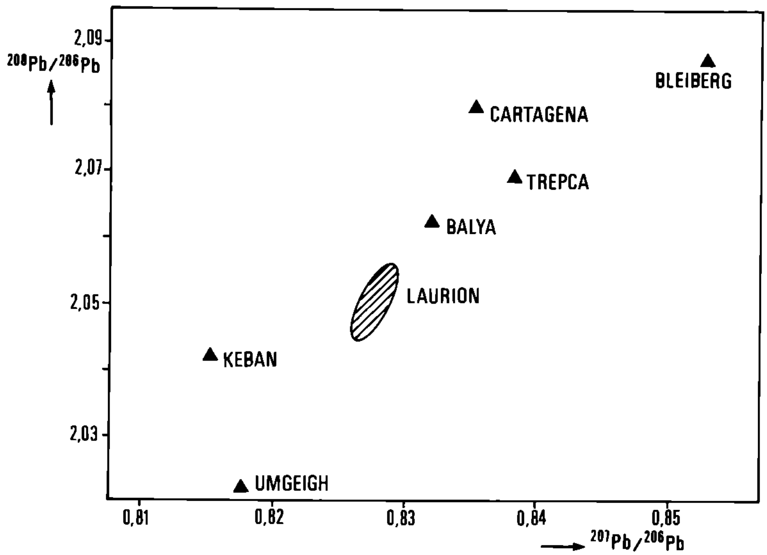

Fig. 9. $^{207}Pb/^{206}Pb$ – $^{208}Pb/^{206}Pb$ diagram using data GALE, 1978.

8. Conclusion

The ore mineralizations of Keban in the SE-Taurus Mountains are products of endogen epigenetic processes. The geochemometric data show some analogy to the lead-zinc-ores of Laurion.

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Literature

CAGLAYAN, H. (1984): Die Vererzung der Fluorit-Molybdänglanzführenden Blei-Zink-Lagerstätten von Keban-Elazig im Südost-Taurus (Türkei). Ph. D. Thesis Univ. Vienna.

GALE, H. N. (1978): Lead isotopes and Aegean Metallurgy. *In:* Vol. I. Thera and the Aegean World (W. W. DOUMAS ed., London).

HUDSON, I. D. (1977): Stable isotope and limestone lithification. Q. J. Geol. Soc. (London), *133*, 637–660.

LAZNICKA, P. (1981): Data on the worldwide distribution of stratiform and strata-bound ore deports. *In:* WOLF, K. H. (ed.), Handbook of Strata-bound and Stratiform Ore Deposits. Vol. 10, Elsevier-Amsterdam, 79–390.

LEULEU, M., MORIKIS, A., PICOT, P. (1973): Sur des mineralistions de type skarn au Laurium (Greece). Mineral. Deposita, *8*, 259–263, Berlin.

KOVENKO, V. (1938): Beitrag über Keban-Lagerstätte. Unveröff. Ber. M. T. A., 1095, Ankara (in Turkish).

MALAKHOV, A. A. (1969): Bismuth and antimony in galenas as indicators of some conditions of ore formation. Geochimiya, *11*, 1283–1296 (russisch).

MAUCHER, A. (1938): Über die Erzvorkommen von Keban-Maden. – Z. prakt. Geol., *46*, 79–84.

MÜLLER, P., SCHNEIDER, H. J., PAREKH, P. P., & ZIMMER, E. (1977): Fluorine contents in carbonate sequences and Rare Earths distribution in fluorites of Pb-Zn deposits in East-Alpine Mid-Triassic. Mineral. Deposita, *12*, 23–36, Berlin.

OELSNER, O. (1960): Möglichkeiten zur Mobilisation von Blei-Zinnkerzen aus bestehenden Lagerstätten und Kriterien zu ihrer genetischen Einstufung. N. Jb. Miner. Abh., *94*, 98–120, Stuttgart.

OELSNER, O.: Kriterien zur genetischen Einstufung von Blei-Zink-Lagerstätten. Z. dt. geol. Ges., *110*, 441–448.

OHMOTO, H. (1972): Systematics of sulfur and carbon isotopes in hydrothermal ore deposits. Economic Geology, *67*, 551–578.

PAREKH, P. P., SCHNEIDER, J. H. (1976): The application of Tb/Ca–Tb/La abundance ratios to problems of fluorspar genesis. – Mineral. Deposita, *11*, 111–116, Berlin.

PETRASCHECK, W. E. (1955): Beziehung zwischen der anatolischen und südosteuropäischen Metallprovinz. Bull. M. T. A. *46/47,* 64–74, Ankara.

(1960): Die alpin-mediterrane Blei-Zink-Provinz. Erzmetall, *13,* 189–204, Stuttgart.

SCHROLL, E. (1954): Ein Beitrag zur geochemischen Analyse ostalpiner Blei-Zink-Lagerstätten. Mitt. Österr. Miner. Ges. Sdh. 3, 1–85 (Wien).

SCHROLL, E. (1979): Progress in the knowledge of indicator elements. *In:* AHRENS, L. H.: Origin and Distribution of the Elements. Pergamon (1984) Press, Oxford-New York, 213–216.

SCHROLL, E.: Geochemical indicator parameters of lead-zine ore deposits in carbonate writes. *In:* WAUSCHKUHN et al. eds., Syngenesis and Epigenesis in the Förmation of Mineral Deposits. Springer-Verlag Bereich Heidelberg, 294–305.

STACEY, J. S., KRAMERS, J. K. (1975): Approximation of terrestrial lead isotope by a two-stage model. Earth Planet. Lett., *26,* 207–221, Amsterdam.

VACHE, R. (1966): Zur Geologie der Variszides und ihrer Lagerstätten im Südanatolischen Taurus. Mineralium Deposita, *1,* 30–42.

ZUSSERMANN, A. (1969): Geological and mining study of Keban Maden. – Etibank-Arsivi, Ankara.