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The role of brines on genesis of Pb-Zn-Ba mineralizations in basement and in cover: the example of Tazekka Pb-Zn district, eastern Morocco.

El papel de salmueras en la formación de mineralizaciones Pb-Zn-Ba en el sócalo y en la cobertura: el ejemplo do distrito de Pb-Zn de Tazekka, Este de Marruecos.

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Abstract

The Tazekka Pb-Zn district, eastern Morocco, includes both mineralized veins and stockworks in the Palaeozoic basement and stratabound deposits in the Liassic carbonate cover rocks. The purpose of this study is to examine the relationship between mineralization seen in the basement and cover by combining field observations, mineralogy, fluid inclusion data and previous stable isotope data and use this information to present a model for the formation of the Pb-Zn ores. The results suggest that the general fluid evolution is similar in most of the studied deposits and is independent of the host rock. The high salinity and low temperature fluids are present in the cover where they are anterior to the mineralization deposition. The wide range of salinities suggests that fluid mixing has occurred, possibly between evaporated seawater brine and a lower salinity fluid. Sphalerite deposition can be interpreted as related to fluids of intermediate salinity probably associated with the mixing process. The resemblance between the obtained results and others concerning Pb-Zn ore deposits across Europe suggests an important water-rock interaction related to a downward migration of the fluids.

Key words: Pb, Zn, basement, carbonate, mineralization, Tazekka, Morocco, Fluid inclusions, brines

INTRODUCTION

The Palaeozoic basement and Liassic carbonate rocks of the Tazekka district of eastern Morocco host numerous Pb-Zn and Ba deposits. Veins of sphalerite, galena, pyrite and chalcopyrite, together with stockwork of quartz and barite are present in Lower Ordovician schists, in an Upper Visean-Namurian volcano-sedimentary complex and in the Tazekka granite. The overlying Liassic carbonate platform sequence contains stratiform Pb-Zn sulphide deposits lying above an unconformity between the Lower and Upper Lias (AUAJJAR, 1987).

The general geological characteristics of the Tazekka district have been described in AUAJJAR (1994) and AUAJJAR & BOULÈGUE (1999).

The purpose of this study is to examine the relationship between mineralization observed in the basement and in the cover by combining field observations, fluid inclusion geochemistry and previously published stable isotopes geochemistry. This information is used to present a model for the formation of the Pb-Zn ores of the Tazekka district.

GEOLOGICAL SETTING

The Tazekka Pb-Zn district is situated in North-Eastern Morocco, southwest of Taza, at the northern end of the Middle Atlas chain. It lies across two contrasting structural domains, the Middle Atlas Causse to the northwest and the Middle Atlas to the southeast (Fig. 1). Deposits include both mineralised veins and stockworks in the Palaeozoic basement and stratiform deposits in the Liassic cover.

The Palaeozoic basement, outcropping in the Tazekka area, includes Lower Ordovician schists and crenulated phyllites (RAUSCHER et al., 1982), overlain unconformably by an Upper Visean-Namurian volcano-sedimentary complex (CHALOT-PRAT, 1990) which comprises andesitic lavas and rhyolitic volcanoclastics (HUVELIN, 1986) and by Variscan granites and microdiorite intrusions. The granite is a monzogranite with quartz, orthoclase, plagioclase, biotite, muscovite, cordierite and andalusite (AMENZOU et al., 2001).

The structure of the Palaeozoic rocks reflects the overprint of two tectonic-metamorphic phases. The first is thought to have been Visean, whereas the second phase, including the formation of late Variscan fractures, is post-Westphalian (HOEPFFNER, 1978 and 1987).

The cover comprises Triassic and Liassic rocks, resting unconformably on the Palaeozoic basement. The Triassic succession includes two formations of red argillite separated by a volcanic episode. The Lower Lias includes three formations: the lowest consists of fine massive dark dolomites; the middle one comprises a succession of dolomitic breccias, laminated and coarsely crystalline dolomites; the upper formation consists of a fine-grained pale grey limestone member and a dark grey limestone member with oolitic and bioclastic intervals. The Middle Lias consists of interbedded limestone and marls, being the latter more abundant towards the top. The Upper Lias-Aalenian and Lower Bajocian are generally marl. In the Middle Atlas Causse, an unconformity between the Lower and the Middle and Upper Lias occurs (ROBILLARD, 1981; SALOMÉ, 1984; AUAJJAR, 1987). The Mesozoic cover is truncated by a series of NNE-SSW to NE-SW reverse faults associated with some frontal overthrusting

(ROBILLARD, 1981). The Moyen Atlas Causse was affected by an important tectonic episode during the Middle Lias and the differentiation of the district into two paleogeographic domains started during the Middle Lias (ROBILLARD, 1981; AUAJJAR, 1987; AUAJJAR & MACQUAR, 1990).

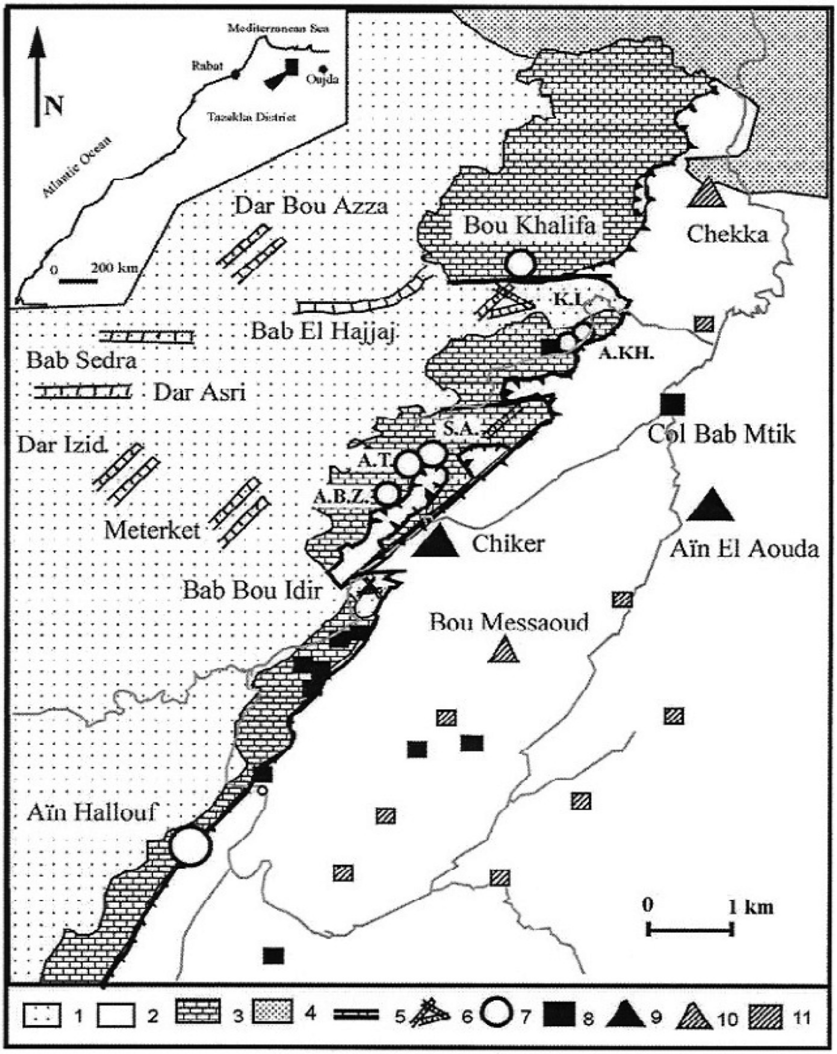

Fig. 1. Geological map of Tazekka district with the location of Pb-Zn(-Cu, Fe) and Ba deposits. 1- Palaeozoic basement; 2- Middle Atlas; 3- Middle Atlas Causse; 4- “Sub –rif”; 5- Pb-Zn quartz vein; 6- Ba-quartz vein; 7- Stratiform deposit; 8- Pb ore deposit; 9- Zn ore deposit; 10- Fe ore deposit; 11- Fe-vein. (AUAJJAR, 1994).

MINERALIZATIONS

Deposits of the Palaeozoic basement

In Tazekka district, mineralization in the basement occurs in the form of quartz-sulphide veins and quartz-barite veins and stockworks hosted by schists, volcano-sedimentary rocks and granites of the Tazekka.

Quartz-sulphide veins

The quartz-sulphide veins are typically either NE-SW (Dar Bou Azza, Dar Izid) or E-W (Bab Sedra, Dar Asri, Bab El Hajjaj) trending, with thicknesses ranging from 1 to 7 m and lengths of a few hundred metres to several kilometres.

Ore deposit	Direction dip	Size	Host	Mineral assamblage
Dar Bou Azza	NE-SW, 60N	HE: 400m D: 1 to 7 m	Schists	Quartz-sphalerite-galena-chalcopyrite-pyrite-tetrahedrite- barite
Dar Izid	NE-SW, 25 to 40 NW NE-SW, 90	HE:250m T: 0.1 to 2m. HE: 200m T: 1 to 2m	Spotted schists	Quartz-galena-sphalerite, pyrite-chalcopyrite-tetrahedrite Galena-chalcopyrite-bornite-malachite-pyromorphite
Meterket - Eastern vein - Western vein	NE-SW NNE-SSW	HE: 200 to 300m T: 80 cm	Andesites of the V.S.C.	Barite-galena-pyrite-chalcopyrite
Bab El Hajjaj	E-W 60N	HE: 3400m T: >500m	V.S.C. and Hornfels	Quartz-barite-galena-tetrahedrite-chalcopyrite-covellite
Bab Sedra E	E-W, 80 ENE-WSW , 60-75N	HE:1600m T: 1 to 4 m	Schists	Quartz-galena- tetrahedrite -chalcopyrite
Dar Asri	E-W	HE: 1100m	Schists	Quartz-galena-tetrahedrite-chalcopyrite- pyromorphite
Bab Bou Idir stockwork	N20,90-55 NNW N60, 90 N90, 90 N120, 90 N130, 45SW	HE: 150m T: 10 to 40cm T: 1,5m HE=100m T: 1m T: 1,5 m	V.S.C.	Quartz-barite-pyrite-galena-sphalerite-tetrahedrite Quartz- barite Quartz- barite Quartz-galena-tetrahedrite-chalcopyrite-barite Quartz-chalcopyrite-malachite-azurite-barite

Koudiat Lakhâa stockwork	N70, 70 SE N90, N120	T: 0.4 to 2m HE: 150m	V.S.C.	Quartz -barite -galena Quartz-barite- galena-pyrite Quartz-barite
Douar Tsaïma stockwork	NNE-SSW N20 80	HE: 650m T: 1 to 4,5m	V.S.C.	Barite

Table 1. Pb-Zn mineralizations of the veins and stockworks of the Palaeozoic basement in the Tazekka district (T=thickness, HE=horizontal extension, V.S.C.= Volcano sedimentary complex).

Quartz-barite veins and stockworks

Barite veins and stockworks are developed only in the Upper Visean-Namurian volcano-sedimentary complex, and are observed at Bab Bou Idir, Koudiat Lakhâa and Douar Tsaïma. A few veins, e.g. veins N80 (Douar Tsaïma), N70 (Koudiat Lakhâa) and N20 (Bab Bou Idir) contain sulphide mineralization. The Bab El Hajjaj vein is the only E-W-trending vein rich in barite.

The eastern part of the E-W Bab Sedra vein truncates a microdiorite dike with an age of 325 Ma, Upper Visean-Namurian A (HOEPFFNER, 1987; CHALOT-PRAT, 1990) or post-300 Ma (HUVELIN, 1986). Vein formation took place in several phases, the older Variscan in age (probably Carboniferous) and the younger is post-Variscan. The barite-rich vein fields of Bab Bou Idir (except vein N20ºE) and of Koudiat Lakhâa formed during the post-Variscan phases (AUAJJAR, 1994).

Deposits of the Liassic cover

The calcareous Liassic platform rocks of Tazekka district contain Pb-Zn and Fe deposits whose distribution is determined by both palaeogeography and structure (AUAJJAR, 1994). To the West of the major North Middle Atlas Fault (NMAF) (N30ºE) the Middle Atlas Causse Domain (MACD) contains Pb-Zn deposits. To the East of NMAF, the Middle Atlas Domain (MAD) includes calamine deposits hosted in Lotharangian limestones, and ferruginous deposits essentially localized at the contact between the truncate Trias and the Lower Lias. The calamine deposits are the result of sphalerite alteration (AUAJJAR, 1994).

The Pb-Zn mineralization is focused along the Mesozoic basin margin, controlled by grabens formed during the major Toarcian - Bathonian Middle Atlas tectonic event. The deposits comprise stratiform (Aïn Hallouf, Asdi Ben Zerhla, Aïn Tarselt Aïn Khebbab and Bou Khalifa) and open-space filling ores (Sidi Abdellah) (Fig. 1, Table 2).

Deposit	Type	Mineral assamblage	Relationship with the host	Evidence of relative age
Aïn Hallouf	Stratiform	Pyrite-chalcopyrite-tetrahedrite –sphalerite- galena-dolomite 3 -quartz- covellite	Dolomite 1 filling cavities depressions, and enlarged fractures in the surface of the Lower Lias	Hydrothermal dolomite 1 as loaves in black marls of the Toarcian
Bou Khalifa	Stratiform	Pyrite-chalcopyrite-sphalerite- galena- dolomite 3-quartz	Dolomite 1 filling enlarged cavities fractures and irregularities in the surface of the Lower Lias	
Aïn Tarselt	Stratiform	Dolomite 1-pyrite chalcopyrite sphalerite-galena-dolomite 3-covellite	Dolomite 1 filling irregularities in the surface of the Lower Lias	
Asdi Ben Zerhla	Stratiform	Pyrite-chalcopyrite-barite-sphalerite-galena- dolomite 3	Dolomite 1 filling irregularities in the surface of the Lower Lias	
Sidi Abdellah	Open-space filling	Barite- dolomite 2-pyrite-tetrahedrite-chalcopyrite-sphalerite-galena- dolomite 3-quartz	Dolomite 2 filling fracture	Ore deposit cross-cutting Domerian limestones

Table 2. Pb-Zn mineralizations of the Middle Atlas Causse.

Stratiform sulphide Pb-Zn mineralization is hosted by hydrothermal dolomites overlying the unconformity between the Lower and the Middle Lias.

METHODOLOGY

The characteristics of the mineralization were determined by optical microscopy of thick and thin sections. Fluid inclusion studies were performed on all three hydrothermal dolomite types and the sphalerite from the cover as well as on quartz 1, barite 1 and sphalerite 1 from the basement.

Prior to microthermometry, all inclusions were optically studied in order to outline the general characteristics of the fluid inclusion populations (primary, pseudosecondary or secondary) based on criteria proposed by ROEDDER (1984). Microthermometry of fluid inclusions was performed on polished thick sections using Chaixmeca (POTY et al., 1976) and Linkam THMSG 600 (SHEPHERD, 1981) heating-freezing stages. The stages were calibrated with melting-point standards at T > 25 °C and with natural and synthetic fluid inclusions at T < 0 °C. The rate of heating was monitored in order to obtain an accuracy of ± 0.2 °C during freezing, ± 1 °C when heating over the 25 to 400 °C range. Salinity, expressed as wt. % eq. NaCl, was calculated from microthermometric data using equations from BODNAR & VITYK (1994).

The volumetric fraction of the aqueous liquid (flw) has been estimated at room temperature by reference to the volumetric chart of ROEDDER (1984).

The existences of gases in the individual inclusions were checked with a LABRAM Micro-Raman spectrometer.

The ionic composition of fluid inclusions was determined by the crush–leach technique (BANKS et al. 1991). The anions F^-, Cl^-, Br^- and SO_4^{2-} were analysed by ion chromatography on double-distilled water leaches using a DIONEX 45001.

RESULTS

Mineralogy

Deposits of the Palaeozoic basement

The quartz–sulphide veins contain quartz, sphalerite, galena, pyrite, chalcopyrite, tetrahedrite and barite (Table 1 and 3); secondary malachite and pyromorphite appear locally. Pyrite and sphalerite occurs only in the NE-SW trending group. Several quartz occurrences are observed: grey and microcrystalline (quartz 1); white macrocrystalline and translucent with comb or rosette textures (quartz 2); or locally pyramidal (quartz 3). Barite exhibits: pink, fine grain massive aggregates (barite 1); large white crystals (barite 2) or "cockscomb" crystal aggregates (barite 3).

The NE-SW trending veins (DBA) show a well-defined mineralogical sequence in different stages (table 3): barite 1 - pyrite - sphalerite 1- quartz 1 (Stage I) - galena 1 and tetrahedrite 1 – (Stage II) - sphalerite 2 – chalcopyrite-1 (Stage III)- barite 2- quartz 2 (Stage IV) - quartz 3 - barite 3- galena 3 (Stage V).

For the E-W trending veins, mineralogical sequence is simpler since stage I and stage II are not present: chalcopyrite (Stage IIIa), galena and tetrahedrite (Stage IIIb), barite 2 - quartz 2 (Stage IV), quartz 3 - barite 3 - galena 3 (Stage V).

In the quartz - barite stockworks and veins, barite forms either large crystals (barite 2) or barite 3 in geodes.

Deposits of the Liassic cover

In the Liassic – hosted Pb-Zn mineralization the sulphides typically form massive aggregates hosted by three hydrothermal dolomite types: early hydrothermal dolomites (dolomite 1 and dolomite 2) and later saddle dolomite (dolomite 3) (Tables 2 and 3) (AUAJJAR & BOULÈGUE, 2002). The early hydrothermal dolomite 1 is a xenotopic dolospar mosaic containing areas of microdolospar, residual zones and microgeodes lined with zoned euhedral dolomite crystals that have dark cores (Fig. 2).

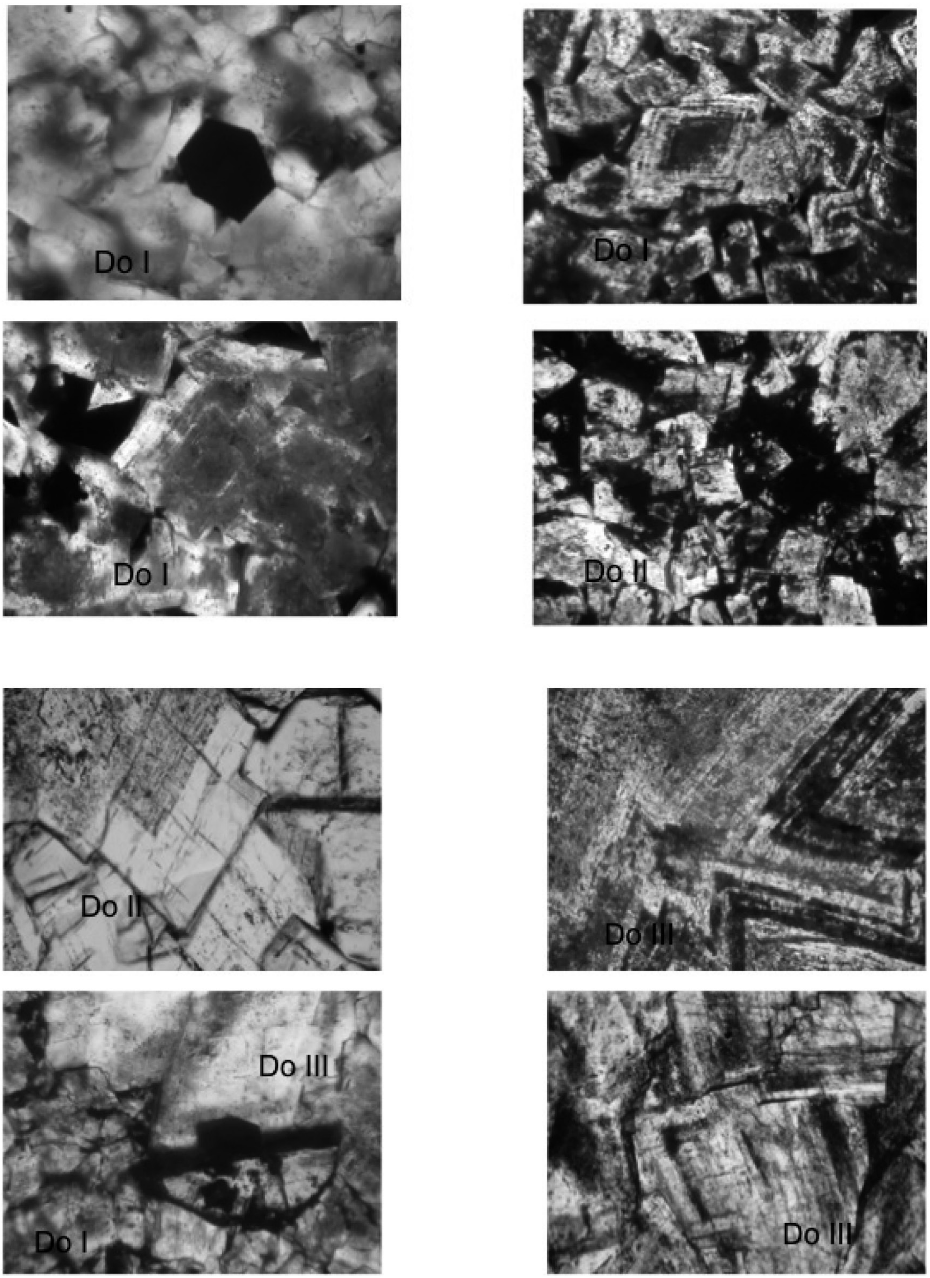

Fig. 2. Hydrothermal dolomites associated with the ore minerals. Two early phases dolomite 1 and dolomite 2 (Do I, Do II) separated in time from a phase of saddle dolomite, dolomite 3 (Do III).

Hydrothermal dolomite 2 well represented at the Sidi Abdellah (SA) deposit, is black, coarsely crystalline and is cut by veins of dolomite 3 up to 15 cm thick. Hydrothermal dolomite 3 or saddle dolomite is coarsely crystalline and occurs filling dissolution breccias, in faults and veins, forming cement in fractures and lining vugs and geodes of many centimetres in diameter. In some geodes dolomite 3 is overlain by bitumen.

At Bou Khalifa (BKh) and Aïn Hallouf (AH), centimetre-sized crystals of sphalerite and galena and minor amounts of pyrite and chalcopyrite are found in dolomite 1. Sphalerite occurs as transparent or translucent red or yellow crystals forming a ribbon or banded texture and contains microscopic inclusions of chalcopyrite and pyrite. Euhedral dolomite 3 crystals also occur crosscutting the galena cleavage. At Bou Khalifa, brecciated sphalerite is cemented by dolomite 3 (Table 3).

	270ºC			160ºC		
	Stage I	Stage II	Stage III	Stage IV	Stage V	
Barite (pink)	—					
Pyrite	—					
Sphalerite 1	—					
Quartz 1						
Galena 1		—				Dar Bou Azza
Tetrahedrite 1		—				DBA
Sphalerite 1			—			
Chalcopyrite			—			
Quartz 2				—		
Barite 2				—		
Quartz 3					—	
Barite 3					—	
Galena 3					—	
			150ºC		145ºC	
Dolomite 1		—				
Pyrite		—				Bou Khalifa
Chalcopyrite			—			Bkh
Sphalerite			—			
Galena				—		Ain Hallouf
Dolomite 3					—	AH
Quartz 3					—	
			150ºC	145ºC	140ºC	
Barite		—				
Dolomite 2			—			
Pyrite			—			
Tetrahedite I			—			
Chalcopyrite			—			Sidi Abdellah
Sphalerite				—		SA
Galena				—		
Dolomite 3					—	
Quartz 3					—	
Quartz 3					—	

Table 3. Stages of mineralization.

At Sidi Abdellah (SA), crystals of sphalerite and galena are associated with chalcopyrite and pyrite. Together, they form massive aggregates in dolomite 2. Microscopic inclusions of chalcopyrite are present in sphalerite and microscopic inclusions of tetrahedrite occur in chalcopyrite. Fractured galena and sphalerite and curved cleavage planes in galena indicate deformation after mineralization. In this deposit chalcopyrite forms cement enclosing brecciated crystals of pyrite. Pyrite occurs in aggregates of subhedral and euhedral crystals. Microscopic inclusions of bournonite are present within the galena. Pyrobitumen occludes intercrystalline porosity of the coarse crystalline dolomite 2.

A phase of supergene alteration of earlier minerals is represented by smithsonite, malachite, covellite and Fe-oxides

Table 3- Stages of mineralization.

Fluid Inclusions

Different fluid inclusion (FI) types were identified based on microscopy and microthermometric data. They are summarised in Table 4 and described: L, for inclusions with global homogenisation to liquid; subscript w indicates the presence of an aqueous phase (water).

Two main fluid inclusion types have been recognised: Lw_1 - H_2O - NaCl- ($CaCl_2$); and Lw_2 - H_2O - $CaCl_2$ - NaCl.

Lw_1 occur in secondary fluid inclusion planes (FIP) in sphalerite and quartz; as pseudo-secondary inclusions in barite from the basement and as primary inclusions in sphalerite and dolomite 3 from the cover.

Lw_2 are present as secondary inclusions in dolomite 1 and as pseudosecondary inclusions in dolomite 2.

Ice melting temperatures of Lw_1 (Tm_{ice}) in sphalerite are between -11 and -3ºC (-11 to -5ºC in the cover and -8 to -3ºC in the basement); in dolomite 3 between -7.2 and -6.5ºC; in barite between -11 and -6ºC; and in quartz are between -6 and -0.5ºC. Homogenisation temperatures (Th) range from 110 to 159ºC in sphalerite (generally lower temperatures in the basement); between 110 and 160ºC in dolomite 3; between 190 and 290ºC in barite; and 200 and 320ºC in quartz (Fig. 3). Lw_2 inclusions are characterised by Tm_{ice} between -23.0 and -11ºC and Th between 90 and 100ºC (Fig. 3)

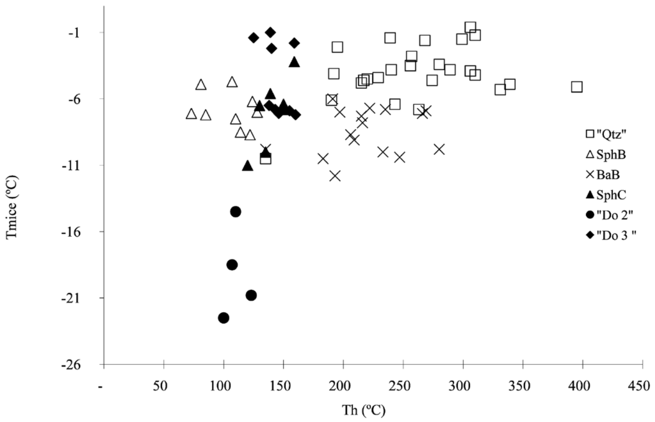

Fig. 3. Microthermometric data-Tmice-Th diagram (Qtz-Quartz, Sph-Spalerite, Do- Dolomite, B-Basement, C- Cover).

Halogens

Crush-leach analyses were carried out on four samples: quartz and barite from veins hosted by Palaeozoic basement; dolomite 2 and dolomite 3, from the Liassic carbonate cover.

The Br and Cl contents of inclusions hosted by quartz and barite from the Palaeozoic basement and of inclusions hosted by dolomite 2 and dolomite 3 from the Liassic cover are represented in Fig. 4a. The Cl/Br molar ratio is lower in minerals than in seawater (Fig. 4b)

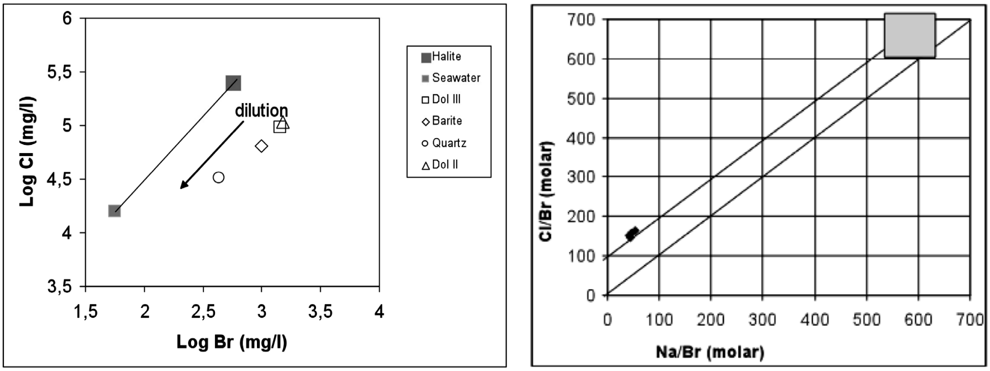

Fig. 4. a) Log Cl - Log Br ; b) Cl/Br and Na/Br ratios.

	DBA Salinity wt%eqNaCl	DBA Th (ºC)	SA Salinity wt%eqNaCl	SA Th (ºC)	BKh Salinity wt%eqNaCl	BKh Th (ºC)	AH Salinity wt%eqNaCl	AH Th (ºC)
Quartz	1 to 15%	135 to 395						
Sphalerite	7 to 13%	73 to 128	0 to 3%	139 to145	5 to 10 %	125 to 150	10 to 15%	120 to 160
Dolomite 1					12 to 18%			
Dolomite 2			16 to 24%	100 to 145				
Dolomite 3			2 to 4%	140 to 150	9 to 10%	130 to 160		125 to 140

Table 4. Microthermometric data.

DISCUSSION AND CONCLUSIONS

The lack of any observable cross-cutting relationships between deposits in the Liassic cover and the basement rocks or geochronological data means that it is difficult to confirm a genetic relationship between the two types. However, the petrographic, fluid inclusion and stable isotope studies suggest that the general fluid evolution is similar in most of the studied deposits.

There is no recognizable geometric relationship between the mineralizations and the igneous rocks from the basement in the Tazekka district.

Hydrothermal dolomites are generally interpreted to have formed as a result of hydrothermal and/or burial alteration of limestones. Many hydrothermal dolomites are associated with Mississippi-Valley-type (MVT) deposits (BRAITHWAITE & RIZZI, 1997, WHITE & AL-AASM, 1997, (LEACH, al., 2010), AUAJJAR & BOULÉGUE, 2002).

Mineralization shows a simple assemblage, essentially sphalerite and galena, with small amounts of pyrite and chalcopyrite (AUAJJAR & BOULÈGUE, 1999). Pb-Zn (Ba) - mineralization hosted in carbonate rocks is very common in North-Eastern Morocco. The Tazekka deposits are typical of this mineralization type, which has a simple mineralogy comprising galena, sphalerite, pyrite and chalcopyrite. Several authors have proposed that these Pb-Zn ore deposits are of Mississippi Valley Type (MVT) (e.g.) and consequently associated with basin margins (LEACH et al., 2001).

At the Sidi Abdellah open-space filling deposit, mineralization is localized in a fracture, which is late- or post - Domerian. The mineralization shows similar mineralogy to that hosted by the Lower Lias rocks below.

At the Ain Hallouf and Bou Khalifa stratiform deposits, deflections of the bedding around large crystals of sphalerite indicate that mineralization predates a deformation stage. At the Ain Hallouf coarsely crystalline dolomite 3 occur overlying Pb-Zn sulphides, cementing broken crystals of galena and sphalerite and dissolution breccias. Euhedral crystals of dolomite 3 are also found within galena crystals but cross-cutting cleavage.

The three types of hydrothermal dolomite are characterized by different $\delta^{18}O$ values. For dolomite 1, which hosts the stratiform ores, $\delta^{18}O$ values vary from -6.1 to -8.7‰ (average - 7.7‰). Dolomite 2 hosting the Sidi Abdellah deposit has $\delta^{18}O$ values around -9.8‰. Dolomite 3 (saddle dolomite) is slightly more variable with $\delta^{18}O$ values of -7.57 to -12.58‰ (average -9.4‰). The two early hydrothermal dolomites (1 and 2) are separated temporally from dolomite 3 and all of them distinct phases. Within ore deposits there is a decrease in $\delta^{18}O$ values from barren to mineralized rocks. (AUAJJAR & BOULÈGUE, 2002).

Field observation, petrographic and stable isotope data suggest a continuous replacement, during the Carixian for the early hydrothermal dolomite 1, and during the Toarcian for early hydrothermal dolomite 2.

The general fluid evolution is similar in most of the studied deposits independently of the host rock. In the mineralised structures, the fluids do not exhibit significant compositional variations namely the fluids associated with sphalerite, independently of the occurrence, in the cover or in the basement. However, the fluids in the basement exhibit an evolution from aqueous fluids with low salt content, to high salinity fluids.

The high salinity and the low temperature fluids are essentially present in the cover where they occur associated with dolomite 2 but they are also represented in quartz from the basement, previous to ore deposition.

The halogens, Cl and Br, tend to act conservatively in solution, as they are not easily incorporated into rock forming minerals. Fluid–rock interactions similarly do not have a significant effect on the concentrations of Cl and Br in solution. Therefore, in the absence of halite, water–rock reactions do not alter the Cl/Br ratio and so this ratio can be used to place constraints on the fluids origin (BANKS et al., 1991).

It is clear that the fluids from the studied samples have a similar range of halogen compositions and that they have lower Cl/Br than seawater. The trend in the data (Fig. 4a) could be interpreted as due to dilution from the cover to basement. The wide range of salinities suggests fluid mixing has occurred, possibly between evaporated seawater brine and a lower salinity fluid. Sphalerite deposition can be interpreted as related to fluids of intermediate salinity probably associated with the mixing process.

The isotopic and fluid inclusion data indicate different temperature of formation of the dolomites with the later phase (dolomite 3) postdating mineralization. The salinities of the dolomite and sphalerite fluids are also different with the high salinity fluids primarily involved in dolomite 2. It is also clear that fluid mixing has occurred and the range of salinities suggests mixing of evaporated seawater brine with a low salinity fluid. The lower salinity fluid is observed in the sphalerite as the primary ore fluid.

The fluids at Tazekka district can be interpreted as an example of a continuous fluid evolution where high salinity fluids (brines) play an important role, which culminates with the deposition of Pb-Zn mineralization associated with a fluid mixing of brines with a lower salinity fluid.

The resemblance between the present results and others concerning Pb-Zn ore deposits across Europe, focus on the origin and evolution of the mineralising fluids, suggests an important water-rock interaction related to a downward migration of the fluids into the basin and even into the basement (CANALS & CARDELLACH 1997; BANKS et al. 2002; GASPARRINI et al. 2003; WILKINSON et al., 2005; BOUCH et al. 2006, among others).

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