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Fluid origin of fluorite-rich carbonate-hosted Pb–Zn mineralization of the Himalayan–Zagros collisional orogenic system: A case study of the Mohailaheng deposit, Tibetan Plateau, China

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ABSTRACT

A significant belt of carbonate-hosted Pb–Zn mineralization occurs in the Himalayan–Zagros collisional orogenic system. Three differing types of these Pb–Zn deposits within this belt have been identified based on variations in gangue mineral assemblages, leading to the classification of carbonate-, quartz- and fluorite-rich classes of Pb–Zn deposits. The third Pb–Zn mineralization (fluorite-rich) type is common in this orogenic system, but little research has been undertaken on it. Here, we focus on the Mohailaheng deposit, a large-sized fluorite-rich carbonate-hosted Pb–Zn deposit (>100 Mt Pb + Zn ores with average grade of 2.18%–4.23%); the deposit is located in the Sanjiang Cenozoic thrust-fold belt, an important part of the Himalayan–Zagros collisional orogenic system and an area that formed during the early Tertiary India–Eurasia collision. The main orebodies in this deposit are stratabound and are hosted by Carboniferous limestones that are located along secondary faults associated with a regional thrust fault. The main assemblage is a sphalerite + galena + pyrite sulfide assemblage associated with a calcite + fluorite + barite + quartz + dolomite gangue assemblage. Detailed field and experimental work indicates that the deposit formed during three distinct phases of hydrothermal activity. Studies on fluid inclusion and stable isotopes of gangue minerals indicate that two dominant distinct fluids involving the deposit formation. They include (1) a low-temperature (130–140 °C), high-salinity (23–24 wt.% NaCl equivalent) basinal brine containing Na^+–K^+–Mg^{2+}–Ca^{2+}–Cl^- ions and abnormally high SO_4^{2-} concentrations, which probably derived from Tertiary basins in the regional district, and (2) a low- to moderate-temperature (170–180 °C) and moderate- to high-salinity (19–20 wt.% NaCl equivalent) metamorphic fluid containing Na^+–K^+–Mg^{2+}–Cl^-–SO_4^{2-} ions and abnormally high F^- and organic matter concentrations, that probably formed during regional metamorphism. Some evaporated seawaters and meteoric fluids were also identified in mixtures with these two dominant fluids. The Pb–Zn mineralization at Mohailaheng formed during three distinct stages, consistent with the regional tectonic history. The first stage involved the formation of favorable lithological and structural traps at Mohailaheng during regional thrusting, leading to the migration of compressed metamorphic waters at depth along a detachment zone, sequestering metals from sediments within the region. Basinal brines at the surface also began to infiltrate down along the secondary faults, dissolving gypsum from the underlying sediments. The second stage was associated with the cessation of thrusting and the onset of strike-slip movements along these thrust faults. Metamorphic fluids containing high concentrations of halogen ions, organic gases, and metals ascended into the structural traps at Mohailaheng along the reactivated thrust faults, causing fluorite, calcite, and some sulfide precipitation. Then, basinal brines rich in SO_4^{2-} quickly descended into the structural traps along the reactivated faults, causing reduction of SO_4^{2-} by organic matter, and producing significant amounts of H_2S. The reduced sulfur then reacted with the metals in the fluids, causing significant sulfide precipitation. The third stage was associated with metal-depleted fluids, which only resulted in the precipitation of calcite from the diluted basinal brines. Combining these findings with research results on other fluorite-rich carbonate-hosted Pb–Zn deposits in the Himalayan–Zagros orogenic system suggests that this type of carbonate-hosted Pb–Zn deposits can also be classified as Mississippi Valley-type (MVT) deposits, and that the origin of the fluorite in these deposits may be related to multiple hydrothermal fluids involved in the mineralization evolution.

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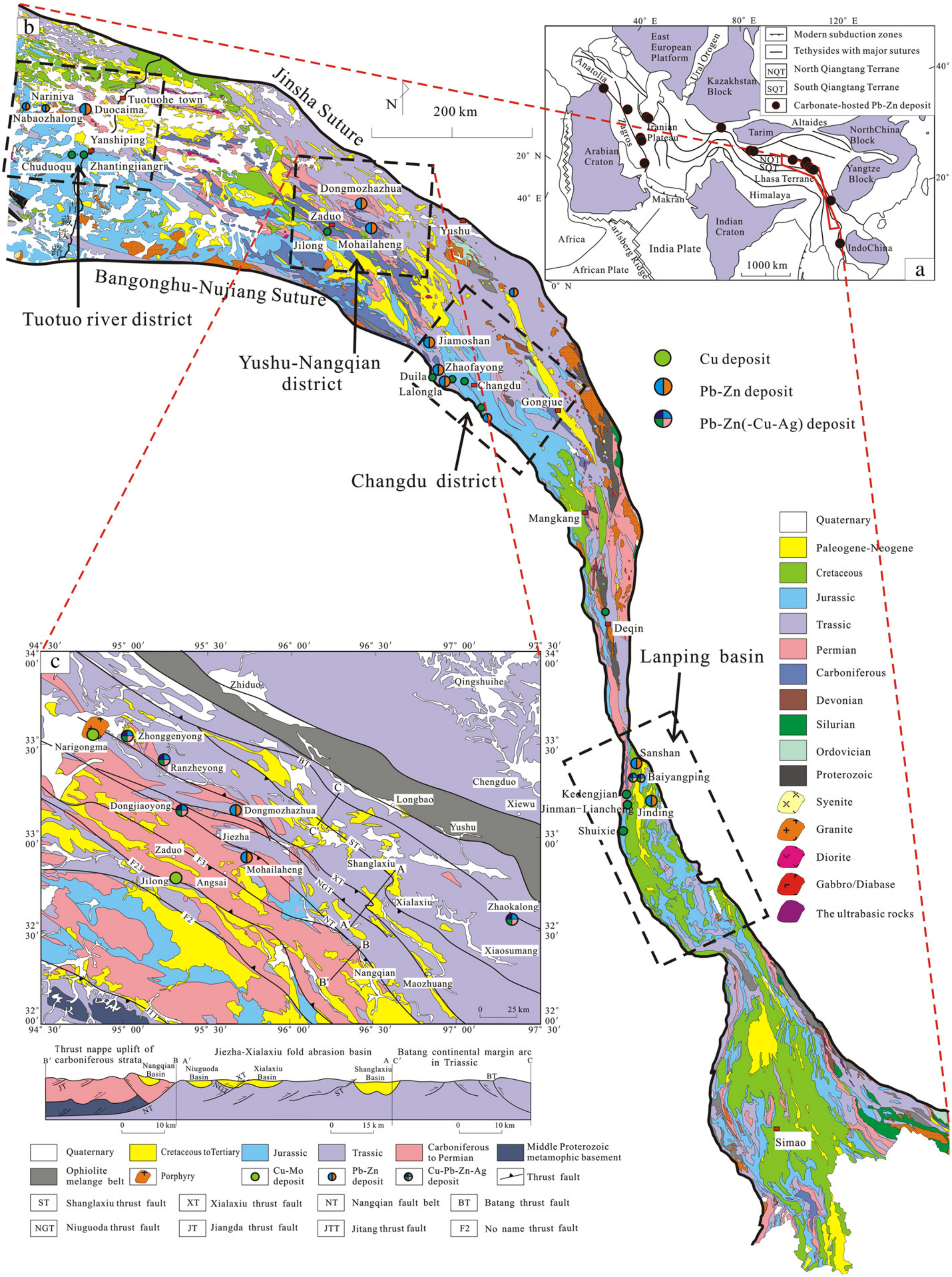
b
Jinsha Suture
N
200 km
Nariniya
Nabaozhalong
Duocaima
Tuotuohe town
Yanshiping
Chuduoqu
Zhantingjiangri
Dongmozhazhua
Zaduo
Jilong
Mohailaheng
Yushu
Bangonghu-Nujiang Suture
Tuotuo river district
Yushu-Nangqian district
Jiamoshan
Zhaofayong
Duila
Lalongla
Changdu
Gongjue
Changdu district
Mangkang
Deqin
Lanping basin
Sanshan
Baiyangping
Kedengjian
Jinman−Lianchen
Jinding
Shuixie
Simao
Cu deposit
Pb-Zn deposit
Pb-Zn(-Cu-Ag) deposit
Quaternary
Paleogene-Neogene
Cretaceous
Jurassic
Trassic
Permian
Carboniferous
Devonian
Silurian
Ordovician
Proterozoic
Syenite
Granite
Diorite
Gabbro/Diabase
The ultrabasic rocks
a
40° E
80° E
120° E
East European Platform
Ural Orogen
Kazakhstan Block
Anatolia
Zagros
Iranian Plateau
Arabian Craton
Tarim
Altaides
NorthChina Block
NQT
SQT
Lhasa Terrane
Yangtze Block
Himalaya
Makran
Indian Craton
Africa
Carlsberg Ridge
India Plate
African Plate
IndoChina
1000 km
Modern subduction zones
Tethysides with major sutures
NQT North Qiangtang Terrane
SQT South Qiangtang Terrane
Carbonate-hosted Pb-Zn deposit
c
94° 30′
95° 00′
95° 30′
96° 00′
96° 30′
97° 00′
97° 30′
34° 00′
33° 30′
33° 00′
32° 30′
32° 00′
Zhiduo
Qingshuihe
Zhonggenyong
Narigongma
Ranzheyong
Chengduo
Longbao
Xiewu
Dongjiaoyong
Dongmozhazhua
Yushu
Zaduo
Jiezha
Mohailaheng
Shanglaxiu
Jilong
Angsai
Xialaxiu
Zhaokalong
Xiaosumang
Nangqian
Maozhuang
25 km
Thrust nappe uplift of carboniferous strata
Jiezha-Xialaxiu fold abrasion basin
Batang continental margin arc in Triassic
Nangqian Basin
Niuguoda Basin
Xialaxiu Basin
Shanglaxiu Basin
10 km
15 km
10 km
Quaternary
Cretaceous toTertiary
Jurassic
Trassic
Carboniferous to Permian
Middle Proterozoic metamophic basement
Ophiolite melange belt
Porphyry
Cu-Mo deposit
Pb-Zn deposit
Cu-Pb-Zn-Ag deposit
Thrust fault
ST Shanglaxiu thrust fault
XT Xialaxiu thrust fault
NT Nangqian fault belt
BT Batang thrust fault
NGT Niuguoda thrust fault
JT Jiangda thrust fault
JTT Jitang thrust fault
F2 No name thrust fault