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## Comment on: Baddeleyite U-Pb age and Hf isotopes, and constraints on genesis of the Panzhihua carbonatite in SW China by Wang et al. (2023)

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## ABSTRACT

Wang et al. (2023) propose that rocks adjacent to the Panzhihua intrusion are not marbles and skarns, but carbonatites. If true, this interpretation could have important implications for models explaining the origin of the large Fe-Ti ore deposits in the intrusion. We reject this interpretation for two principal reasons: 1) the objects described as “mantle xenoliths”, and considered, incorrectly, as diagnostic of carbonatite, are in fact deformed and altered mafic/ultramafic intrusions; 2) the concentrations of incompatible trace elements in the marbles are low and typical of metasedimentary rocks, not carbonatite.

Wang et al. (2023) propose that rocks adjacent to the Panzhihua intrusion, which have been mapped as marbles and skarns, are carbonatites. If true, this interpretation could have important implications for models explaining the origin of the large Fe-Ti ore deposits in the intrusion.

The authors advance the following arguments to support their interpretation:

- The rocks adjacent to the south-eastern part of the gabbroic intrusion are massive without underlying and overlying strata, and clastic layers and interlayers could not be identified.
- Large-scale marmorization (transformation of sedimentary carbonate to marble) was not developed adjacent to the intrusion
- The carbonatites usually consist of olivine, clinopyroxene, orthopyroxene, calcite, and dolomite, and no felsic minerals or hydrous minerals were found
- Abundant dunite, lherzolite and olivine lamprophyre mantle xenoliths constitute the most important evidence of magmatogene carbonatite because only igneous rocks can host xenoliths

We will not comment in detail on these arguments, other than to point out that 1) a clear transition from unmetamorphosed dolomite to marble can be mapped in the field, 2) relict sedimentary structures are found within the contact aureole, and 3) hydrous minerals such as brucite, serpentine and hydrogrossular are common in the rocks in the contact aureole. Instead, we focus on the last argument and add another that we find pertinent.

1. “Xenoliths”. The objects identified as “mantle xenoliths” are enormous. The authors state that the largest are “tens of meters in dimension”, and those illustrated in their Fig. 2a appear to be more than 60 m long. The manner in which mantle xenoliths were carried from their source deep in the mantle to the surface has long puzzled petrologists and current models do not satisfactorily explain the transport of even relatively small, centimetre- to metre-sized, mantle xenoliths in alkali basalts and kimberlites. A possible explanation is the presence of abundant phenocrysts that increases the magma’s viscosity to the extent that it can support fragments of dense ultramafic rock. The transport of decimetre-sized fragments of dense ultramafic rock in phenocryst-free carbonatite magma, whose viscosity is two orders of magnitude lower than normal basalt, seems inconceivable.

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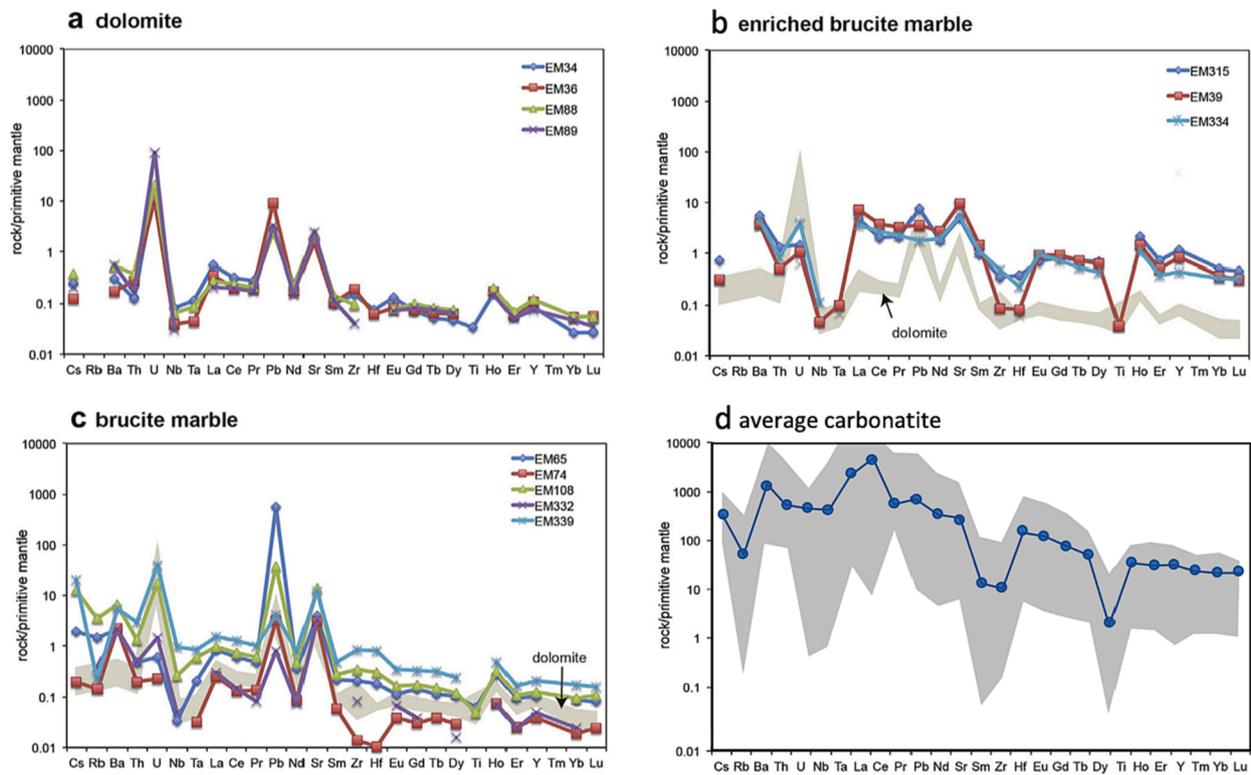
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**Fig. 1.** Trace elements, normalized using the primitive mantle values of Hofmann (1988), comparing a, b, c - the concentrations in dolomites and marbles adjacent to the Panzhihua intrusion (diagrams from Ganino et al., 2013) with d - the compositions of carbonatites (data from DIGIS team, 2022). The blue line with round symbols is the average of over 2000 samples, the grey field extends from maximum to minimum values.

A brief survey of the literature reveals that carbonatites rarely contain mantle xenoliths. According to Woolley and Church (2005), mantle xenoliths are extremely uncommon in intrusive carbonatites and although some “mantle debris” is found in extrusive carbonatites, the average size of these objects is about 3 cm and rarely more than to 15 cm (Jones et al., 2000). Contrary to the authors’ claim, the presence of mantle xenoliths is not diagnostic of carbonatite.

In our opinion, the large objects described as xenoliths are mafic dykes that intruded the sedimentary rocks that surround the Panzhihua gabbro. These dykes were dismembered and deformed, and they interacted with the marble during emplacement of the gabbro to produce the rounded forms and reaction zones (zebra rock) that are conspicuous in many outcrops. Fig. 2b in Ganino et al. (2013) shows a large complex dyke in the Zujiabaobao mine. Its lower portion is tabular but at higher levels, the unit is disrupted by the plastic deformation that is recorded in strong folding of metamorphic foliation in the marbles. The petrographic descriptions and chemical analyses of dykes intruding the marbles reported by Ganino et al. (2013), Hou et al. (2013) and Tang et al. (2017) shows that these rocks have compositions ranging from diorite to picrite, compositions that are very different from the mafic to ultramafic compositions of mantle xenoliths. Wang et al. (2023) do not provide chemical analyses of their “xenoliths” but their descriptions and photos are consistent with an origin as olivine-phyric basalts and picrites whose mineralogy and compositions were modified during interaction with the Mg-carbonates they intruded.

2. *Major and trace element geochemistry.* Wang et al. (2023) either did

not conduct chemical analyses of samples of their “carbonatites” and “xenoliths”, or they chose not to report their analyses. This is surprising because trace-element abundances readily distinguish carbonatites from marbles and skarns (e.g., Bowden, 1968).

Ganino et al. (2013) report the major and trace element contents of unmetamorphosed limestones and dolomites in locations remote from the Panzhihua intrusion and of marbles and skarns within the contact metamorphic aureole adjacent to the intrusion. These compositions are reproduced in Fig. 1 which compares the levels of trace elements in dolomites, marbles and skarns from the Panzhihua locality with the average composition of over 2000 carbonatites worldwide (DIGIS Team, 2022). The figure shows that the concentrations in the skarns are higher than those in unmetamorphosed carbonaceous sediments; but even in the skarns, the concentrations are 3–4 orders of magnitude lower than in the average carbonatite. The histograms of Ce contents plotted as Fig. 2 illustrate the large gap between the compositions of all the rocks from the Panzhihua metamorphic aureole and those of global carbonatites.

We recognise that some carbonatites, typically those in oceanic islands, do contain low concentrations of incompatible trace elements but these carbonates are spatially and genetically related to nephelinites, phonolites and other silica-undersaturated alkaline rocks (e.g., Munoz and Sagredo, 2012). Such rocks have not been identified in the Panzhihua region.

On the basis of these arguments and data, we conclude that it is highly unlikely that the calcareous rocks adjacent to the Panzhihua intrusion are carbonatites and we maintain the interpretation advanced

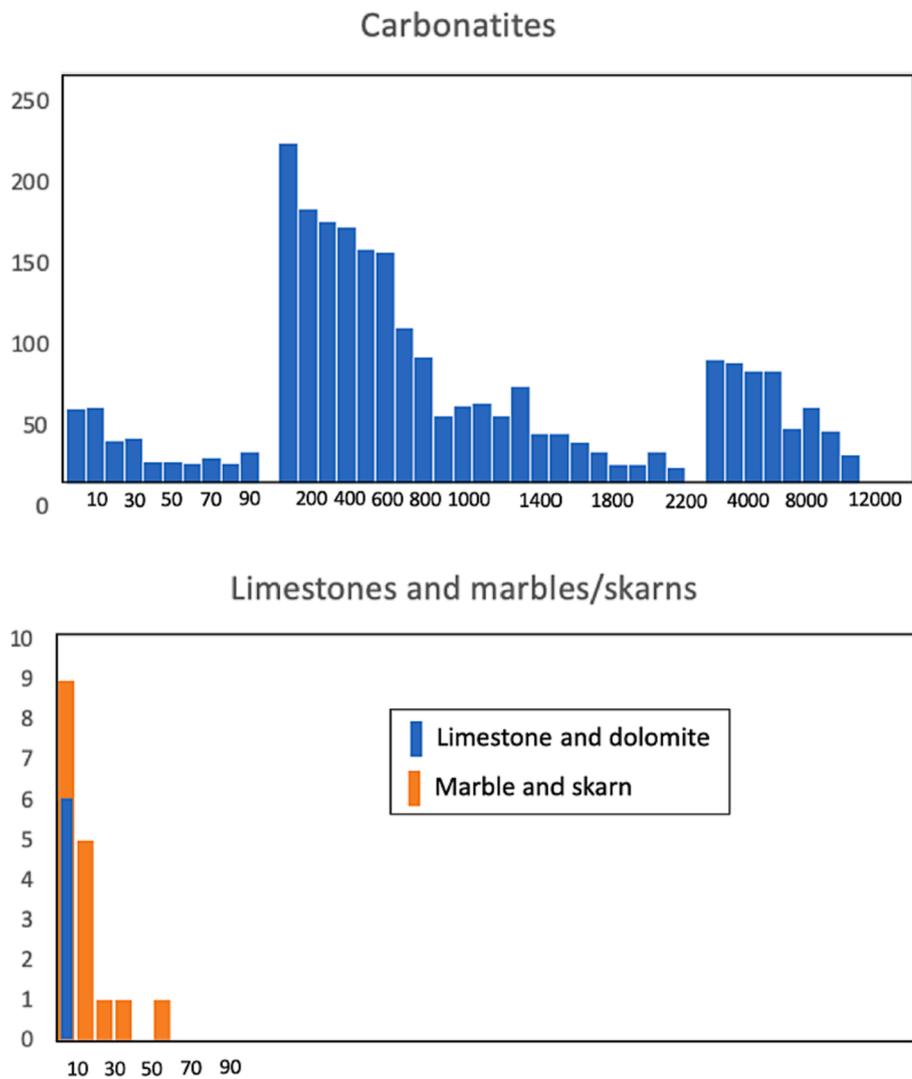


Fig. 2. Histograms comparing the ranges of cerium concentrations in dolomites and marbles adjacent to the Panzhihua intrusion with concentrations in global carbonatites (data from DIGIS team, 2022). The scale for carbonatites is split into three sections: 0 to 100; 100 to 2000; 2000 to greater than 12000.

in Zhou et al. (2005), Ganino et al. (2008, 2013), Hou et al. (2013) Tang et al. (2017) and other authors familiar with the Panzhihua geology, according to which these rocks are dolomites that had been metamorphosed and metasomatized during the intrusion of the gabbroic intrusion.

#### Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

#### Data availability

Data will be made available on request.

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