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On Geological CO_2 Emissions

What we know and what we don't know about

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Abstract

Geological CO_2 emissions from intraplate regions remain poorly quantified despite their relevance to the long-term carbon cycle. Observations from the Pannonian Basin indicate measurable mantle-derived degassing, highlighting the need for improved constraints on non-volcanic geological CO_2 fluxes.

Keywords: Carbon dioxide; pargasosphere; degassing; Pannonian Basin

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1. Introduction

"In scientific debate, it is neither power nor authority that should carry decisive weight, but only scientific truth itself" (Ferenc Deák, 1803−1876, Hungarian Stateman). When an Academy of Sciences distances itself from non-mainstream or less widely accepted scientific views, it does not strengthen public confidence—on the contrary, it risks weakening it. Avoiding open discussion for strategic, political, or institutional reasons may create the impression that the Academy is unable or unwilling to engage in transparent, evidence-based dialogue. Such avoidance does not protect science; instead, it endangers public trust, fosters misunderstanding, and ultimately diminishes citizens' confidence in scientific institutions. A genuinely strong scientific community demonstrates its integrity not by avoiding challenging questions but by addressing them openly, rigorously, and respectfully.

In this context some important issues must be discussed indeed appears to be "Beyond the Climate Change Consensus" such as the significance of geological CO_2 emissions and the global knowledge gap in this regard.

2. Uncertainities

Geological carbon dioxide emissions represent a fundamental but still poorly quantified component of the global carbon cycle. Despite the well-documented dominance of anthropogenic sources over volcanic CO_2 at present, the natural geological flux from Earth's interior continues to play an essential role in regulating atmospheric CO_2 over geological timescales. One of the central challenges is that our understanding is heavily biased toward areas of active volcanism, while intraplate regions — far from magma chambers and subduction zones remain critically under sampled and poorly constrained.

Modern global estimates of volcanic CO_2 emissions range between 0.18 and 0.44 Gt/year, including both eruptive and non-eruptive degassing sources. By contrast, anthropogenic emissions exceed 35 Gt/year. Although this comparison emphasizes the minor role of volcanoes in today's atmospheric budget, these volcanic estimates do not include diffuse, tectonically controlled, or deep-mantle-derived CO_2 fluxes outside volcanic arcs. Recent studies show that continental regions without active volcanism can still host significant mantle-derived CO_2 release. For example, mantle volatiles continuously ascend along large lithospheric deformation zones and extensional structures in the Pannonian Basin, with estimated mantle-related CO_2 fluxes of 10^3–10^5 mol km^{-2} yr^{-1}, values comparable to fluxes from quiescent volcanic systems. These findings challenge the traditional view that significant mantle degassing only occurs near magmatic centers. The problem is the massive data gap in intraplate regions. A critical theme emerging from all uploaded studies is that geological CO_2 fluxes in intraplate settings remain largely unconstrained. The 'pargasosphere hypothesis' explicitly predicts that cooling asthenosphere beneath young lithosphere can generate diffuse CO_2 emanations even far from active volcanism (Fig. 1.). Deep lithospheric mantle beneath continental interiors can store and subsequently release large quantities of CO_2 over millions of years, especially during phases of lithospheric rejuvenation, thermal relaxation, and metasomatism. Recent data from the Bakony–Balaton Highland Volcanic Field indicate CO_2 accumulation of ~103 Gt over 10 Myr during post-rift lithospheric thickening. Degassing studies across the Pannonian Basin reveal that mantle- derived CO_2 is transported through lithospheric deformation zones, even in the absence of magma, producing fluxes overlapping with volcanic systems. Together, these results show that deep lithospheric CO_2 flux is neither negligible nor spatially restricted, yet global models currently lack robust parameters for these contributions.

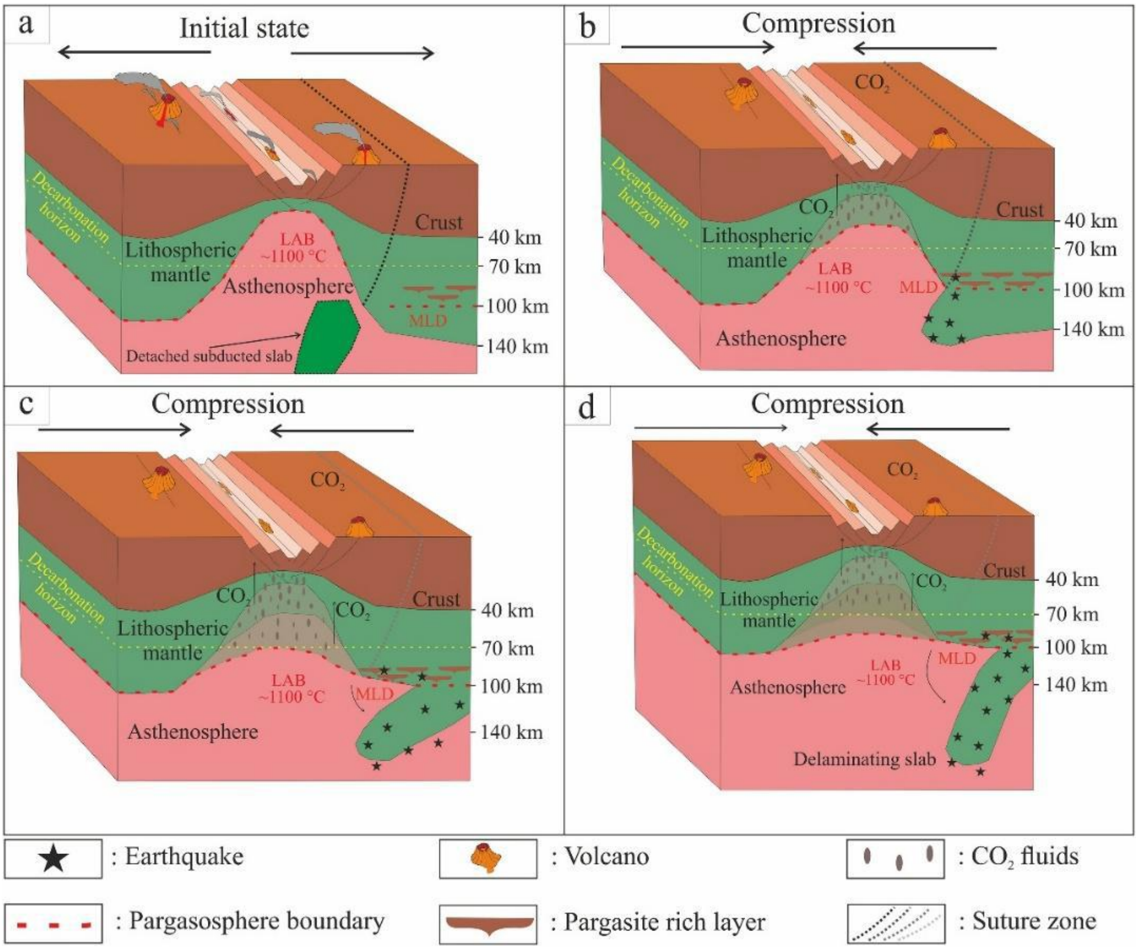

Figure 1: The cooling asthenosphere can be the source of significant amount of CO_2 (Fig. 5 in Kovács et al., 2021).

Geological CO_2 emissions—such as those derived from: 1) deep-rooted fault zones; 2) degassing of trapped fluids or partial melts in the lithospheric mantle or at the lithosphere–asthenosphere boundary; 3) metamorphic decarbonation in lower crustal settings; 4) inherited CO_2-rich lithospheric mantle reservoirs, remain one of the least quantified fluxes in the global carbon budget. In regions like the Pannonian Basin, noble gas systematics, C–He ratios, and isotopic fingerprints demonstrate a complex mix of mantle, crustal, and atmospheric components, with extensive subsurface CO_2 trapping, dissolution, and re-release processes that complicate flux estimation. Moreover, the new xenolith-based constraints show that lithospheric mantle processes can accumulate enormous CO_2 reservoirs, which may episodically release carbon during tectonic or thermal disturbances. This dynamic behaviour is almost entirely missing from current climate-carbon system models.

2. Consequences

Because diffuse geological emissions outside volcanic arcs are still poorly measured, current climate models likely underestimate the natural lithospheric–mantle CO_2 flux. This underestimation has two major consequences: 1) It oversimplifies the natural baseline of pre-industrial atmospheric CO_2; 2) It complicates attribution studies aiming to separate anthropogenic from natural contributions on millennial to million-year scales. The uncertainty does not diminish the dominant role of human emissions today, but it means that the long-term evolution of atmospheric CO_2 cannot be fully understood without integrating intraplate geological sources. Research targeting diffuse CO_2 degassing in intraplate environments—such as the Pannonian Basin—will directly contribute to constraining the magnitude of deep mantle CO_2 fluxes, improving global carbon cycle models, refining geodynamic interpretations of lithosphere–asthenosphere interactions, providing essential data for paleoclimate reconstructions, reducing the uncertainty of natural CO_2 sources in global climate assessments.

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