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大陆岩石圈、地幔底部异常体与地幔对流相互作用的数值模拟

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The interaction between the continental lithosphere, surrounding mantle and thermochemical piles in the lowermost mantle

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摘要 在地球表层存在着占地表面积约30%的具有低固有密度、高黏度的大陆岩石圈.由于其特殊的物理化学性质，大陆岩石圈通常不直接参与下方的地幔对流，但其与地幔对流格局有着重要的相互影响.大量研究显示，在中太平洋和非洲的下地幔底部，存在着两块占核幔边界（CMB）面积约20%的高密度热化学异常体（由于其剪切波速度较低，常称作低剪切波速度省（LSVPs））.LSVPs的演化既受地幔对流的影响，同时也影响地幔物质运动的格局和动力学过程.本文系统研究了存在大陆岩石圈，下地幔LSVPs的地幔对流模型.模拟结果显示：（1）当大陆体积较小时，其边缘常伴随着俯冲，大陆区域地幔常处于下涌状态，其上地幔温度较低，大陆岩石圈在水平方向处于压应力状态.随着大陆体积的增大，大陆边缘的俯冲逐渐减弱，大陆区域地幔由下涌转为上涌，其上地幔温度较高，大陆岩石圈水平方向处于拉应力状态.（2） 岩石圈与软流圈边界（LAB）在大陆下方较深，温度较低；在海洋区域较浅，温度较高.随着大陆体积的增大，陆洋之间LAB深度、温度的差异逐渐减小.（3）大陆区域地幔底部LSVPs物质的丰度与大陆的体积呈正相关.当大陆体积较小时，大陆下方的LSVPs丰度比海洋区域少.随着大陆体积的增大，大陆下方LSVPs的丰度逐渐增大.（4）海洋地区地表热流高，且随时间波动大，大陆地区地表热流低，随时间波动较小；LSVPs区域的核幔边界热流低.

关键词 大陆岩石圈, 下地幔热化学异常, 地幔对流, 相互作用

Abstract: Continental lithosphere with low intrinsic density and high viscosity occupies about 30% area of the Earth's surface. Due to its special physical and chemical properties, the continental lithosphere does not actively take part in the mantle overturn. However, it affects the convective flow and vice versa. Below central Pacific ocean and Southern Africa lie two high-density thermochemical piles, covering ~20% of the Core Mantle Boundary (CMB) area. The structure of these thermochemical piles is influenced by the convective flow in the surrounding mantle. On the other hand, these thermochemical piles have important effects on the structure of mantle convection. Thermochemical convection models including continental lithosphere and thermochemical piles are used to investigate the interaction between the continental lithosphere, surrounding mantle and the thermochemical piles. Our model results show that (1) Violent subduction at continental margins, downward flow and low upper mantle temperature under continental region, and compressive horizontal stress in continental lithosphere characterize the main feature of the mantle when the size of the continental lithosphere is small. When the size of the continent is large, subduction at continental margins becomes weak; mantle under continents flows upward; temperature in the upper mantle is high, horizontal stress in the continental lithosphere is tensile. (2) Lithosphere-Asthenosphere Boundary (LAB) in the continental region is deeper and colder than that in the oceanic region. With the increase of continental size, these differences decrease. (3) The abundance of thermochemical piles in continental region is positively correlated with the size of continental lithosphere, i.e. low for small continental size and high for large continental size. (4) Surface heat flux is high and fluctuates violently with time in the oceanic region while low and fluctuates weakly with time in the continental region. CMB heat flux under thermochemical piles is lower than the surrounding mantle region.

Keywords Continental lithosphere, Thermochemical piles, LSVPs, Mantle convection, Interaction

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