Scientists participating in workshops have mentioned that knowledge-holders should be made aware about the types of benefits accrued from local knowledge. Details on the benefit share about bioresources should be provided to the community at the time of research. One copy of the signed prior informed consent (PIC) must be handed over to the traditional knowledge-holders about a particular knowledge/practice. Information about traditional knowledge can be kept in the regional institute/university as a ready reference under confidential documents. In case, a dispute arises in future over a particular knowledge or practice on biodiversity, this document may serve as a legal document. If a scientist adds value to a particular plant-based knowledge or develops new formula, then he holds the right to ask for a greater share of the benefit. However, benefit may be allocated to the knowledge-holder as well. Commonly known practices or knowledge may be put in the public domain to develop a chain of like-minded people on entrepreneurship development.

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RESEARCH NEWS

Recent insights into deep mantle mineralogy

A. V. Sankaran

Deep down in the earth's lowermost mantle region, between ~2600 and ~2900 km depth, lies a geologically important zone more commonly referred to as the core–mantle boundary (CMB). This zone with a compositionally stratified thermo-chemical layer is the provenance for many deep mantle plumes, the source for a major amount of the earth's heat flux, partial melting, the final resting place for the subducting slabs, a zone having high *P–T* phase transitions and displaying mineral anisotropy. In the last few years there has been a spurt in mineral physics studies investigating the behaviour of the deep mantle minerals under high pressure and temperature. These have highlighted the region's little known features and improved our conception of the chemical and thermal structure of the CMB, and also explained many of the associated enigmas.

Interest on the narrow CMB zone gathered momentum after the detection of a sharp seismic velocity discontinuity known as the D″ discontinuity, nearly three decades ago, showing 2–3% *s*-wave velocity increase between 250 and 350 km (116–125 GPa), just above its boundary with the core. This discontinuity, which is non-uniform in its seismic velocity structure globally, was initially thought to reflect abrupt compositional differences between this D″ region and the rest of the lower mantle, or arising from mineral phase transitions among the mantle minerals[1,2]. However, in 2004, high-pressure experiments and quantum mechanical calculations revealed that when Mg-silicate perovskite, the most common mineral in the lower mantle, was heated to 2500 K and >125 GPa, conditions of deep lower mantle, it restructured to a new uncommon form called postperovskite (pPv). This transition to a new phase was accompanied by 1–1.5% density increase and changes in the elastic properties, and it became clear that this solid–solid phase transition was responsible for the D″ discontinuity[3–5]. The experimenters determined the *P–T* boundary conditions for this perovskite (Pv) to pPv transition, which was also found to exhibit a strongly positive pressure–temperature relation (positive Clapeyron slope).

The phase transition observed at the top of the D″ layer was found to be strongly influenced by both thermal and chemical heterogeneities present in this region. In fact, theoretical and experimental studies have indicated the presence of a thermal boundary layer in the CMB region introducing a geothermal gradient as a consequence of heat transfer from the adjacent hotter outer core by thermal conduction across the CMB[6]. As a result of this thermal gradient, phase boundary conditions for phase transitions or crossings in and out of the pPv phase were predicted; these crossings may be either single, double or multiple, depending on the number of geotherm intersects and each such crossing exhibiting a corresponding seismic signature[6]. According to this model, variations in seismic velocity discontinuities with depths should reflect variation in mantle temperature. The estimated pPv phase boundary temperature at CMB pressure of 136 GPa was approximately 4000 K. Though absolute temperature conditions at CMB are far from settled, values of 3700–4400 K have been derived from melting point of iron at the inner core boundary[4]. Thus, wherever the higher temperature estimate exists, the conditions would place the lowermost D″ layer within the Pv stability field, but where the lower estimates prevail, pPv is supposed to be the dominant phase.

As anticipated in the double-crossing model, a second discontinuity below the velocity increase already observed at the top of the D″ layer (Pv layer) has now been detected in the lowermost D″ region. The latter discontinuity, a velocity decrease, has been observed below a few regions like Eurasia, Cocos region (South America), Central Pacific, and Central and North America[7,8]. The temperature-dependent phase crossings and the depths of such phase changes, combined with data from Clapeyron slope on phase boundary conditions have been used to characterize the prevailing thermal structure and infer the related mineral phases of the lowermost 100 km of the mantle. Below Eurasia, the lower and upper discontinuities were observed 55–85 km (reduction in velocity) and 206–316 km (increase in velocity) respectively, above the CMB, while beneath the Caribbean region the variation was larger: 66–286 and 126–416 km above the CMB. These topographic variations are considered to imply large temperature gradients laterally, estimated to be around 700–900 K along the upper discontinuity beneath Eurasia and 1300–1700 K beneath the Caribbean. These variations have been ascribed to the presence of folded subducted oceanic lithosphere (palaeosubduction) that had penetrated up to the CMB region. Low seismic velocities that have been detected at the edge of the lithospheric slab are believed to arise from the displaced material (upwelling) from the thin, hot thermal boundary layer present at the top of the CMB[9].

New findings during the last few years have led to the interpretation of the observed seismic signatures in the D″ layer from different perspectives and have considered them as emerging due to various causes such as mineral anisotropy, partitioning of incompatible elements among the mineral phases, and due to the spin and valence states of iron under increasing *P*–*T* of the D″ depths. Though the lower mantle is generally isotropic, small regions have shown seismic anisotropy, particularly in places of palaeosubduction or mantle upwelling. It has been found that the *s*-waves propagating through the mantle and the D″ region undergo polarization and get split into two waves – a faster horizontal wave and a slower vertical wave, the splitting resulting from the anisotropic behaviour of Pv and pPv, the constituent mineral phases exhibiting strong lattice preferred orientation (LPO). The LPO is believed to be induced by convective flow mechanism in the boundary layer above the CMB, where crystals of the relatively more anisotropic pPv phase, owing to its favourable crystallographic structure (silicate layers parallel to 010, serving as the glide plane) more easily take the preferred orientation. The velocity changes due to such anisotropy are strongly pronounced in regions of upwelling convective stream, as for example, below the Central Pacific[4,5]. But a recent experimental study found that where the pPv phase developed in a downwelling stream, the splitting of the *s*-waves resulted in a faster vertically polarized wave, unlike the behaviour of the polarized wave in regions of mantle upwellings[10]. Interestingly, since the properties of the pPv phase answer many of the seismic signatures in the D″ layer (seismic discontinuity, its magnitude and anisotropy), this mineralogical phase is considered to be dominant here[4].

Recent studies have also highlighted how elements incompatible in the mantle, such as Na, K, U, Th, get preferentially accommodated within the layered pPv structure and influence the chemistry of the upwelling magmas. An important finding is about the entry of iron into the pPv phase, which is found to stabilize this mineral phase even beyond the limits determined earlier. This is observed in experiments where synthetic Mg–Fe silicates with varying amounts of Fe when heated to 2500 K at pressures of 130–165 GPa in a diamond anvil cell transformed to a pPv-like phase in all the samples[11,12], even at pressures of 144 ± 10 GPa. These studies concluded that the entry of a large amount of oxidized iron preferentially into the pPv phase compared to other mantle minerals extends its limits of stability. Such an enrichment of iron in the pPv phase is possible since the hotter layers at the base of the D″ layer are in contact with the Fe-rich outer core, which should facilitate easy local interaction and influx of Fe into the pPv silicate phase. Iron incorporation can not only alter the stability boundary conditions but also the seismic signatures, density, buoyancy, thermoelasticity and geochemistry[11,12]. However, a recent experimental study questions the assumed direct contact of the lower mantle with the outer core, as according to this study, the two zones seem to be separated by a layer showing *P*-wave velocity reduction, indicating possibly an intervening chemically distinct buoyant liquid layer that may hinder this reaction[13].

Yet another study has described how the spin and valence states of iron, two important parameters, can sway several physical and chemical properties of the iron-bearing silicates in the D″ layer such as their density, seismicity, heat transfer, and thereby alter the thermo-chemical state here[14]. Iron, a transition element, can adopt different electronic configurations, and in the extreme *P*–*T* conditions of the deep interior, the spinning electrons in iron pair-up. When the electrons are in unpaired state, iron is said to be in 'high-spin state' and when they pair-up, it is said to be in 'low-spin state'. Apart from these spin states, the material can also exist in between these two states, when it is said to be in 'intermediate-spin state'. Further, iron in the lower mantle exists in both divalent and trivalent states, and electrons in a divalent atom can change or rapidly oscillate to the trivalent state and vice versa. This rapid oscillation is responsible for the thermal conductivity in the region.

Mineral physics studies under a wide range of high pressure and temperature were carried out to explore the spin states of iron in dominant lower-mantle minerals such as Mg silicate, Pv, pPv and ferripericlase using synthetic oxides of ferroperilase ($MgO_{0.75}$, $Fe_{0.25}$) under ultrahigh pressure and temperature relevant to lower mantle conditions[14]. These revealed the complexity of the mineral over a large range of depth, as both the high and low spin states occurred in the same crystal structure and the spin changeover was continuous over extended lower mantle pressure. This zone called the 'spin transition zone' is found to stretch from about 1000 km (1900 K) depth to 2200 km (2300 K) depth where the high-spin, unpaired electrons gradually changed to the low-spin, paired electron state. At a depth of 2200 km, the transition stopped and the low-spin state became the dominant phase of the ferropericlase. This latter spin state has higher density and faster seismic velocities relative to the high-spin ferropericlase and can affect the temperature and heat conductivity in the lower mantle, besides the overall geochemistry[12,15].

The D″ layer bordering the molten Fe outer core undoubtedly has complex physical and chemical properties. Considering their key role in global dynamics and crustal evolution, there is an increasing scope for investigations through mineral physics, seismology, geodynamics and geochemistry for interpreting thermal heterogeneity and mineralogical features of the deepest part of the mantle to evolve a comprehensive picture of the structure and dynamics of the deep earth.

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COMMENTARY

Reclamation and reuse of treated municipal wastewater: an option to mitigate water stress

Manish Kumar

Growing population, industrialization, agricultural practices and urbanization have increased the water demand and hence the quantity of wastewater (ww). Availability of drinking water, including different components of daily per capita demand in developing countries, is becoming a serious issue to manage. To fight with growing water stress, reclamation and reuse of treated ww for various day-to-day uses except for drinking purpose is necessary. Reuse of ww in Indian cities, not a substantial but a small fraction, may bridge the gap between supply and demand of water in the future. This also deals with a viable technological option for reuse of ww.

With growing population, advanced agricultural practices, industrialization, urbanization and multiple use of water have increased the demand for water. Climate change leads to major impacts on regional water resources, affecting both groundwater and surface water supply for domestic and industrial uses. These impacts will be more severe in the developing world, because of their poor capacity to cope with and adapt to climate variability. India also comes under this category. Natural bodies of surface water, such as lakes, rivers, reservoirs and other impounding structures are major sources of raw water which is used for community water supply after necessary treatment. The increasing water demand will lead to a clear stress on these water bodies. In future, treatment of raw water would become more cumbersome and costly due to contamination, which is to be brought down to permissible limits.

Due to daily human activity and also various agricultural and industrial operations, wastewater (ww) is produced in enormous quantity. Due to lack of management and treatment facilities most of the municipal ww generated in Indian cities is discharged into aquatic systems without treatment, making the receiving body unfit for its desired use in the years to come. Inadequate treatment facilities for sewage have deteriorated the water quality of aquatic resources. The latest study carried out by the Central Pollution Control Board (CPCB) indicates that about 26,254 million litres per day (Ml/d) of ww is generated in the 921 Class I cities and Class II towns in India (housing more than 70% of urban population). The municipal ww treatment capacity developed so far in India is about 7044 Ml/d – accounting for 27% of ww generation in these two classes of urban centres. Table 1 presents a scenario of ww generated and treated for the year 2001 for the Indian states. The table clearly shows inadequate treatment facility and management. The situation is much worse because most of the states show that ww generated is directly discharged into the nearby surface water.

There is an urgent need to plan strategies and give thrust to policies with equal importance for the development of ww treatment facilities and reuse. The future of urban water supplies for potable uses will grossly depend on efficient ww treatment systems and reuse, as the treated ww of upstream urban centres will be the source of water for downstream cities.

Reclamation and reuse of ww – a case study

In India, where ww treatment facilities in Class II cities are in the developmental stage, reuse of treated water is still a distant dream. However, in bigger cities (metros), reuse of ww may be made mandatory. In cities like Delhi, where ww treatment is more stringent and a major portion of the waste is treated, the reuse facility may be implemented effectively. A case study of Delhi is given below. Based on this study, a scheme may be proposed for other big cities also as an option to meet their future water requirement and to mitigate water stress.

Delhi is experiencing increasing pressure to meet its demand for its water resources. Growing urbanization, improvement in living standards and exploding