Figure 3. *Palmacites tsokarensis* sp. nov. ***a***, Palmate leaf in reflected light, × 0.4; specimen no. 39272. ***b***, basal portion of another specimen in reflected light, × 0.8; specimen no. 39273.

(maximum 1 cm). *Trachycarpus ladakhensis* Lakhanpal *et al.*[4], known from the Liyan Formation, differs from the present fossil specimen in having an irregular, semilunar ring-like hastula and smaller lamina of length 19 cm and width 14.6 cm.

As our fossil specimen is different from all the known species of *Palmacites*, it is being described here as a new species, *P. tsokarensis* sp. nov.; the specific epithet is after the locality Tsokar from where the fossil was collected. Its presence not only indicates that palms were abundant during the middle–late Eocene in the region, but also suggests that the area had not attained as much height as it has today (about 5000 m amsl). The present fossil, along with *Livistona*, indicates tropical conditions during the depositional period. The discovery is also important for enriching the palaeoflora in view of the paucity of palaeobotonical material from the Tertiary of Ladakh, especially from the Indus Suture Zone.

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Tapping earth's upper-mantle methane gas resource at a nuclear drilling initiative area, Palk Bay, India/Sri Lanka

The first practical concept for drilling through the Mohorovicic seismic discontinuity stratum to penetrate the upper mantle for geochemical investigative purposes was proposed[1] during 1957. Later, Thomas Gold (1920–2004) in the USA and others active in the former USSR since the insightful 1951 hypothesis of Nikolai A. Kudryavtsev (1893–1971), alleged the existence of enormous commercially valuable methane deposits deep in the earth, giving geo-science and geo-resource specialists a truly down-to-earth reason to undertake such a technically challenging and financially speculative effort in the quest for an almost 'unlimited' energy resource, derived solely from a degassing earth-mantle, to power human civilization. *In situ* production of methane under laboratory conditions[2] replicating those that exist in the earth's upper mantle was first accomplished by 2004. Methane generation is likely to occur at temperatures ~ 500°C when ambient pressure is <7 GPa and such conducive conditions are expected to be found at depths of 100–200 km inside the earth[3]. Industrial tapping of this suspected energy resource entails development of the world's biggest 'gas field'.

According to Herndon, natural mantle-generated methane is pushed towards the base of the earth's crust and is emplaced there by Herndon's postulated earth-mantle 'thermal tsunamis'[4], but only to be drastically retarded at the underside of the Mohorovicic seismic discontinuity stratum. Herndon's innovative 'thermal tsunamis' theory apparently also justifies R. B. Cathcart's earth-georeactor sedimentation theory based on inversion, which focused on the possible initial aggregation several billion years ago, of a natural georeactor at the earth's centre of mass instigated by energy pulses caused by innumerable asteroid impacts into a speculative global magma 'ocean' as the planet accreted[5]. Herndon[6] further postulates that a non-negligible sub-Mohorovicic stratum mantle energy resource – heating caused by local compression of mantle material during his 'Whole earth Decompression Dynamics' scenario – will be operative in addition to radioactivity and viscous deformation of the earth crust owing to sporadic and periodic cryogenic events (such as past and future 'Ice Ages') atop our planet's crust[7].

Noticed by Andrija Mohorovicic (1857–1936) in the early 20th century, the Mohorovicic stratum is a geological boundary layer, possibly a 'contact' between the earth's crust and the underlying mantle; it is a seismic wave-velocity discontinuity so distinct that geo-science has named the volume of material above as 'crust' and that below as 'mantle'. The depth of occurrence of the Mohorovicic stratum varies, ranging from ~ 5 km under the world-ocean to 35–60 km beneath continents. The Mohorovicic stratum is variously estimated to be ~ 0.2–3 km thick. In other words, the global volume of the geological layer of the Mohorovicic comprised of solids/liquids/gases could range from $\sim 1.0112 \times 10^8$ to $\sim 1.5319 \times 10^9$ cubic km. (By comparison, the volume of the world-ocean is $\sim 1350 \times 10^6$ cubic km.) In light of Herndon's recent geochemical evidential summary posted on-line at arXiv.org, is it possible that the Mohorovicic stratum is really a wrung-out planetary shell, emptied of water that is now circulating in the earth's hydrologic cycle because the earth has decompressed since its initial natural formation eons ago as a kernel of coalesced material inside a Jupiter-like planet that eventually lost its primary enveloping atmosphere due to an extreme Sun-generated solar wind? By Herndon's theory, today's air is earth's second gaseous envelopment (atmosphere).

As yet, early 21st century, there are still only two practical technical means expected to directly reach the Mohorovicic stratum vertically: Option I using Mohole-type equipment[8] technically advanced over equipment currently operated by the Joint Oceanographic Institutions for Deep earth Sampling. The Japanese-led team is following a risky course of costly fieldwork actions essentially repeating USA's earlier experience – but with remarkable technical improvements – using the purpose-built drillship *Chikyu* ('Earth' in Japanese). By 2012, when the existing Kyoto Protocol expires, the Japanese-led drilling team may be prepared to pass through the Mohorovicic stratum. Option II using a nuclear thermal drill devised by William Mansfield Adams (1932)[9]. Adams legalized his concept on 24 December 1963 with USA Patent 3,115,194 'Nuclear Reactor Apparatus for Earth Penetration', now lapsed. Adams' mainly tungsten apparatus is still quite difficult to successfully design and to properly manufacture. A new insulation material, tungsten diselenide[10], has the lowest thermal conductivity ever measured for a fully dense material; this ultra-low thermal conductivity is achieved using disordered, layered WSe_2 crystals that transmit only 0.05 W/m/K at room temperature. The 21st century R&D on Adam's concept will create an embryo science, 'lithodynamics', based on facts presented in a scheme akin to other sciences (aerodynamics and hydrodynamics). Instead of a nuclear reactor, packaged fission nuclear reactor high level waste – cesium, strontium and yttrium immediately removed from an operating nuclear reactor – will provide the heat needed to melt rock[11] and therefore energize a self-sinking rock-melting probe[12] to descend to the mantle from the Nuclear Drilling Initiative Area (NDIA) geomer[13]. Both rock penetration techniques have the potential capability, either because of the presence of a continuous drill string (Option I) or a trailing telecommunications fibre (Option II) extending upwards beyond the planet's ground surface, to convey data[14] to supervising humans remaining safely atop an artificial island at the NDIA situated in an industrialized Palk Bay, east of the Sethusamudram Shipping Channel Project slated for completion by 2008 at a cost of 2006 USA$ 560,000,000.

If the NDIA were exploited using the mobile Chikyu-type offshore drill rig, then a single 1 m dia 40 km long coring cylinder of Archean age material excavated from Dharwar craton[15] as muck would require the unified Indian/Sri Lankan macroproject implementers to deposit ~ 126,000 cubic m of muck somewhere in close proximity of *Chikyu*. (That is ~0.315% of the 40,000,000 cubic metres of material planned to be dredged to create the Sethusamudram Shipping Channel Project.) By contrast Option II, an Adams-type nuclear drill, falling gravitationally at a fairly constant rate, would melt the various rock types – including basalt and granite – through which it passes while it simultaneously produces a high-density sealing glass liner; subsequently it might be followed by a specially formulated high-density anti-corrosion 'drilling mud' spike loaded into the hole. (Crushed barite 'drilling mud' has a density of 2883 kg/cubic m; costly and poisonous liquid mercury has a density of 13580 kg/cubic m, ~ 13.2 times that of sea water.) The thin, destabilized rock barrier separating the rock melter from the trailing spike will be naturally fragmented by forces coming from below and from the hole sides. Stably pressurized to maintain an open drill hole, gas bubbles and even gas streams will be afforded a vertical route of migration, thereby induced to ascend through the superincumbent 'drilling mud' spike, permitting all gases present to reach the earth surface for safe industrial collection and to then be pumped through buried steel pipes or seafloor-draped flexible hoses to mainland-based storage tank farms in India and Sri Lanka. Secure island storage sites on Delft (49.8 sq. km) and Velanai (68.3 sq. km) are additional possibilities. The glass lining of the melted vertical shaft, and pressurized drilling 'mud', must effectively function as an external pressure vessel[16]. Rock-melting is 'aseptic' in that it does not introduce anthropic chemical mixtures during the drilling operation; to an inconsequential degree, the trailing drilling mud will do so unavoidably. Then, from shore-based tsunami-proof gas storage tank farms, mined earth-mantle methane gas could be introduced to the domestic gas pipeline transmission networks of India and Sri Lanka for eventual distribution to consumers. Gas pipelines will have to be built in southern India since they do not yet exist as a widespread and comprehensive infrastructure. If the methane removed is liquefied, then it may be marketed via tanker lorries using the main highways of India (conveying supplies to Krishnagiri, Bangalore, Chennai, Nagpur and Kharagpur), as well as to Sri Lanka (Mannar) and all cities to the east of Mannar (Trincomalee), south (Sri Jayawardanepura/Columbo) and north (Jaffna). India's energy consumption increased[17] nearly 210% between 1980 and 2001; Sri Lanka's total energy consumption is also increasing and its future needs must be met economically.

As Palk Bay is peacefully shared by both nations, it is assumed that India and Sri Lanka will efficiently cooperate politically as well as commercially in any Palk Bay industrialization macroproject. The area of India plus Sri Lanka equals 3,353,200 sq. km, so the fraction of the earth's total area (153,295,000 sq. km) occupied by them is 2.187%. In other words, India and Sri Lanka will surely be entitled to legally harvest at least 2.187% of all methane generated by the earth's mantle below the Mohorovicic stratum. No indisputable international law on this point exists! Only a direct explorative contact, with subsequent remote geochemical assessment, can result in a proper determination of the estimated total amount of methane gas that might be safely exploited continuously from the earth-mantle resource. With a market value of a few cents/cubic m, the annual income from commercial recovery, not operational profit, to pay for its widespread commercial public distribution will be small. However, a cubic metre of methane has an energy content of 9500 kcal and a daily production of 1.5 million cubic metres of methane gas has an energy value approximately equal to 10,000 barrels of oil; a world oil price of 2006 USA$50/barrel means that India and Sri Lanka could reserve for other purchases an expenditure of about 2006USA $162,000,000 for every 10,000 barrels of oil not imported. According to the currently accepted geochemical theory, the earth's sub-surface methane gas component is presumed to be constantly regenerating within a 100–200 km thick shell of mantle material! It may vigorously migrate laterally in the upper mantle.

The Archean craton beneath NDIA is approximately 40 km thick and may have a geothermal gradient of about 15–30°C/km; the up-engineered Option II Adams-type nuclear rock melter is probably best suited for penetration of such thickness of crust. How penetrable (also described as 'drillable'[8]) is the presumed 40 km thick stratum of varying rock types – Jaffna limestone (density ranges from 2160 to 2560 kg/cubic m), granite (density = ~1025 kg/cubic m), basalt (density = ~3000 kg/cubic m) – of which the NDIA geomer is composed? Coined after the start of the Space Age in 1957 by the Canadian geographer Hans Carol (1915–71), a geomer is a named three-dimensional region of a terrestrial-type planet's geographic substance, a segment of Earth-surface, explored, exploited and notably modified by industrialized and industrializing groups of people[19]. Russian drillers reached >12 km with their Kola Peninsula Super Deep Borehole and German drillers at the KTB-Borehole also had practical deep-drilling experience during the 20th century[20]. Between 1966 and 1984, six stratigraphical wells were bored in the region: Pesalai 1, 2, and 3 on Mannar Island; Palk Bay-1 and Delft-1 wells in Palk Strait; and Pedro-1. However, what substrates actually underlie the Jaffna limestone remains still a geological penetration planning uncertainty – a big 'IF' – until thorough scientific probing gives NDIA a clear stratigraphical definition as a geomer. Some geochemists speculate that exothermic chemical reactions of volatile water with silicates may exceed radioactivity as a source of earth-crust heat[21]. (It is possible that natural partial melt magma chambers will be encountered and, if so, macro-engineering considerations about the generation of electricity from magma pocket heat are warranted[22]. It is possible that unnatural magma chambers may be manufactured.) Using zeolite[23] Kremenetsky and Shaderman have attempted to harvest valuable materials such as rhenium at Kudriavy Volcano on Iturup, one of the Kurile Islands in Russia. Thus, it is possible to harvest elements from the induced gas flow emerging from the melted rock mine utilizing 'la roca magica'[24]. Carbon dioxide, helium, argon, uranium, thorium and potassium are the most assured NDIA well-products[25]. To obtain access to the sub-Dharwar craton mantle methane, India and Sri Lanka probably need to only fully penetrate and maintain an open well through the Mohorovicic stratum below the NDIA, thus markedly expanding the supportive territorial volume of the settled India–Sri Lanka geomer. In other words, NDIA-produced resources will increase the 'ecological footprint' – the idea was first bruited in 1999 by scientists in The Netherlands concerned with calculation of the 'carrying capacity'[26] of countries and regions – of India and Sri Lanka.

The *Chikyu*, which will commence its internationally sponsored Integrated Ocean Drilling Programme in 2007, presently has an existing capability to suspend a drill string ~9.5 km long; that length is inadequate for the proposed NDIA macroproject task. (It is worth mentioning that the special *Chikyu* drilling mud used is intended to buoy the drill string.) Furthermore, *Chikyu* operations are inordinately expensive in terms of both isolating highly skilled manpower and complicating periodic equipment maintenance; even a large ship is subject to inclement weather, making tightly timetabled operations difficult. Option II Adams-type nuclear drill must be based securely on a small, geomorphically stable Sethusamudram Shipping Channel Project dredge spoil island that would be safe during tsunamis, such as that of 26 December 2004, as well as from any likely future local manifestation of global sea-level rise[27]. All technologies developed at NDIA will subsequently be commercially applicable to earth's land area – 29% of the planet's surface. This presents the happy economic prospect for technology and equipment leasing or sales to other ecosystem-nations and business consortiums.

India has a well-advanced peaceful nuclear energy development programme, with 15 nuclear power plants on-line and eight more being constructed. Since the R&D basis already exists, India and Sri Lanka must improve a more than forty-year-old public domain macro-engineering concept for a planet crust-penetrating nuclear drill and utilize the perfected technology to gain energy independence[28]. There is no underplaying the technical enormity of the NDIA geomer macroproject: it will be a 21st century Apollo Lunar Mission Programme-like challenge to R&D, but it could lead to innumerable commercial spin-offs (tunnelling technology, deep automated mining, materials science advances, quick HLW disposal instead of long-term water pool storage – especially of dangerous minor actinides, plutonium, iodine and technetium – and further progress in science and technology best left to the imagination of informed persons. A programme aimed at tapping the gas resource of the earth's mantle seems worthwhile since it involves a static technical goal and Nature is not likely to mount countermeasures[29]. It is worth noting that 2009 marks the centenary of Andrija Mohorovicic's seismological discovery.

The earth's sub-Mohorovicic stratum methane gas resource, if tapped commercially, i.e. by a large-scale industrial installation at the NDIA geomer, offers India and Sri Lanka the prospect of an independent long-term 'methane energy economy'[30], comparable to the prospective 'hydrogen energy economy' but without the ugly exhumation of underground and open-cast mine sites and massive damaging combustion of coal, which could induce a new kind of local and post-use global atmospheric pollution problem[31]. (The 4–5 km deep Iceland Deep Drilling Project just commencing is meant to validate the energy supply concept of Iceland as the hydrogen energy 'Kuwait' for Europe and elsewhere[32].) Universal heat mining, as in the sustainable extraction of thermal energy from hot dry rock[33] stops being practical at depths >3 km because the porosity and permeability of rocks is too low to permit fluid circulation. There is also the unresolved controversy on the true heating effect on the earth's atmosphere of the increasing presence of anthropogenic carbon dioxide and methane[34].

The simplest hydrocarbon, methane gas, traps ~ 21 times more heat per molecule than carbon dioxide, making it a strong greenhouse gas. Even in a drill site surface equipment environment of intermittent dynamic loading of wellhead equipment, a methane gas well 'blow out' at the NDIA geomer must to be made technically improbable. A short-term gas blowout will have nearly null effect on the earth's atmosphere since it can simply be set aflame, making its potential for global atmospheric warming as an uncontrolled globalized greenhouse gas injection virtually nil. During any uncontained well 'blow-out' of long duration, there is the possibility for the eventual creation of an isolated artificial volcano in Palk Bay spewing mantle materials such as gassy lava and aerial particulates; long-term presence of an active anthropogenic volcano with a widespread dust fallout footprint would drastically change the climate of the region[35]. Such an eruption would also destroy the high-value NDIA installation and pose a direct and immediate survival threat to the people of at least two ecosystem-states. To prevent a blowout, the Japanese have employed an unusually capacious wellhead casing – an internal pressure vessel – aboard the world-ocean restricted *Chikyu*, to stabilize their drill-site activities. Earth's surface may have endured already at least two natural episodes of mantle-derived methane blow-outs during the Jurassic and Cretaceous that disrupted the carbon cycle markedly, according Yvonne van Breugel, who recently found clear evidence of sudden large-scale releases.

Tapping methane from the earth's mantle and developing it as an energy resource agreeably shared by India and Sri Lanka, is a high-risk but possibly worthwhile economic endeavour. A new working definition of a 'gas field' will become necessary if the NDIA macroproject is successful. Abiotic methane gas tapping cannot be classified as a 'windfall' drawn from a fixed-for-all-time national territory endowment; rather, it is an ultimately undefinable renewable energy resource that can be accessed only by progressive R&D. Public investment in such R&D is a legitimate component of a forward-looking India–Sri Lanka regional development programme. The earth's deepest 'gas field' must to be a target of exploitation for innovative exploration because the financial gain and technological advancements are extremely promising in a global sub-surface geological shell with enormous potential. Its vigorous exploitation cannot cause ground subsidence that sometimes is clear evidence – on the landscape and in the seafloor – of large-scale coal mining and petroleum/gas extractions. All post-1957 (Space Age) human science and technology may stimulate thoughts of resource accession using Adams' tool, an adaptation of Option II nuclear rock melting device, favouring inspired macroprojects in the crusts of other planets in the Solar System.

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