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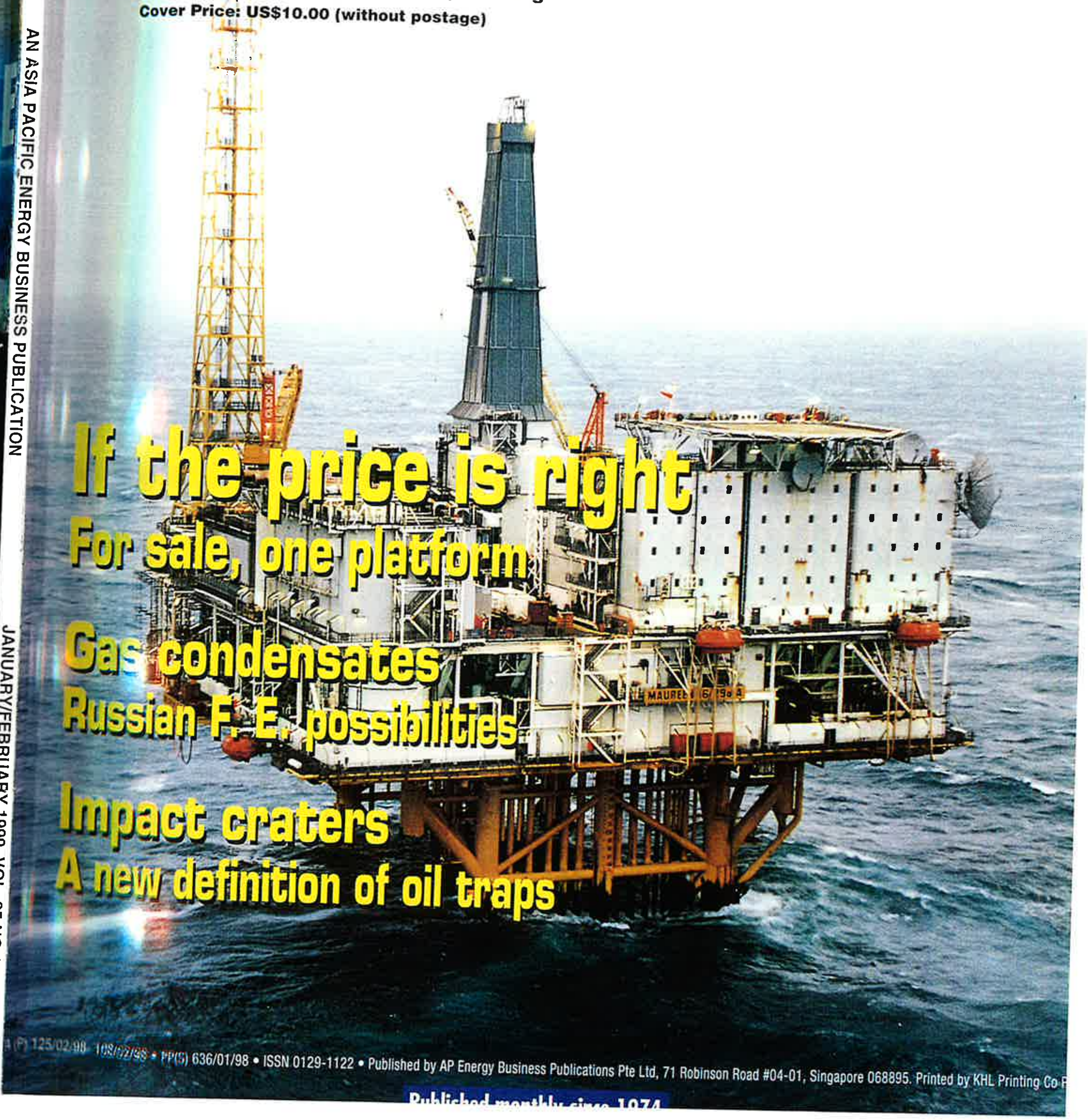

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A South China Sea Copernican event

Presented to a sceptical audience of geologists at a meeting in Singapore last year, this paper, by Dave Buthman of Unocal, initially created some humour, humour which was rapidly replaced by brow-furrowing, contemplative thought, as the possibilities began to emerge. Geology may never be the same again.

The simplest, most common and abundant geologic features in the terrestrial solar system are impact craters. The Moon hosts over 50 giant impact craters with diameters ranging from 300 to over 3,200 kilometres in diameter. Erupting and filling these large basins on the Moon are the extensive *mare* basalts. The Lunar Highlands occupy the outer crater rim areas. In the crater centres, single or multiple rebound peaks may exist. A host of radial and concentric tectonic features populate the craters, including fractures, faults, rills, and volcanic vents. The unstable inner slopes of the crater rims exhibit mass wasting, terracing, concentric normal faulting, and the basin floor itself may exhibit fractures, extruded lavas and isostatic readjustment features. If the Moon had available the dispersive agents, wind and water, then sediments would undoubtedly fill in the crater basins. On Earth, because of resurfacing, deposition and erosion, the remaining, pervasive effects of those impacts are not always apparent. If Copernican-scale craters could be identified on Earth, they would undoubtedly underpin a host of geologic phenomena from sedimentary basins, volcanism, to orogenesis, to regional and local tectonic fabrics.

Lunar Orbiter 05 image of the lunar crater Tycho (Lunar and Planetary Institute).

Tektite ejecta

Tektites are fused glass particles of impact melt, strewn tens to thousands of kilometres from impact sites. Tektites have lead to discoveries of impact craters at Chicxulub, Mexico, Bosumptwi, West Africa and at Chesapeake Bay, off the U.S. Atlantic coast. The discovery of tektite ejecta in ODP Core 612 off the U.S. Atlantic coast lead to the eventual discovery of an Eocene crater 80 kilometres in diameter and nearly a kilometre deep at Chesapeake Bay. Confirming evidence included reflection seismic data and petrographic analyses of the ejecta exhibited shocked quartz, microkrystites, stishovite and coesite. Later, wells were drilled that determined the crater was filled and obscured by 350 metres of breccia (Poag, 1998).

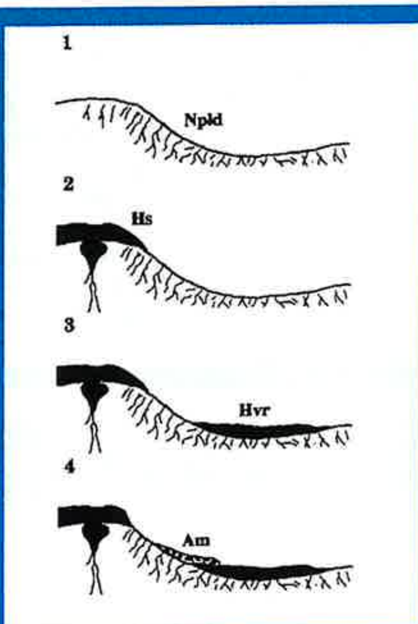
Evidence that confirmed the Ivory Coast tektite field being the result of excavation at the later discovered Bosumptwi crater, include ground-penetrating radar and wells. The Chicxulub Impact Basin, Yucatan, Mexico, is thought to be the source of the world-wide tektite glass ejecta layer associated with the Cretaceous/Tertiary extinction event. Chemical links have been established between the Chicxulub crater and its ejecta layers 1,700 kilometres to the east at Beloc, Haiti, and over 2,000 kilometres to the north-west in Colorado (Sharpton and Marin, 1997).

During the late nineteenth and early twentieth centuries, geologic field parties, in search of oil, discovered and mapped the Australasian Tektite Strewnfield. Because of the wide distribution of tektites across the Australasian Theatre, researchers have long suspected, but never located, the impact event or events responsible for distribution of the tektites (Buthman, 1998).

Kinematics of impact

When explosives are detonated underground, a cavity forms in the immediate vicinity, surrounded by a zone of permanent deformation and, surrounding that, a zone of elastic deformation. When an asteroid or comet or meteorite strikes Earth, the most obvious result is the cavity, or the crater excavation. Other less obvious consequences, much more distant from the impact site, are seismic shock waves, hydrospheric ripples, atmospheric perturbations and deep mantle induced fractures, which initiate volcanism and geothermal anomalies. If the impacting object strikes the hydrosphere or water-saturated sediments, for example in a deltaic or shallow water setting, the typical impact breccias and planar deformation features will not form (Buchanan and others, 1998), and the resultant crater generally has a much larger width-to-depth ratio. If the impactor strikes more competent rock strata, or regolith, impact brecciation and metamorphism will accompany the typical structural assemblages of concentric and radial folds, faults and fractures, and the excavation cavity will be relatively deep and narrow. The impactor may strike thin brittle basaltic crusts, thicker granitic continental crusts, or any of an infinite combination of crusts, and the tectonic consequences may not become apparent for hundreds of millions of years.

On the Moon, the large impact basins, like *Mare Imbrium*, formed by impact approximately 4 billion years ago, yet the *mare* basalts now filling the basin were extruded 3.2 to 3.9 billion years ago (Spudis and Adkins, 1998). On Mars, the 1100 kilometre diameter *Isidis Planitia* basin formed approximately 4.2 billion years ago, yet the concentric fault conduits did not extrude the *Syrtis Major* volcanics until 3.3 to 3.75 billion years ago (Craddock, 1998). In both the Lunar and Martian examples, volcanism post-dated the basin-forming impact event by several hundred million years.



Geologic history of Isidis Planitia and Syrtis Major Planum, Mars (Craddock, 1994). 1100 km diameter Isidis Planitia impact depression and fractures (top) and later emplacement of Syrtis Major Formation (Hs) volcanics. Initial impact 4.2 billion years ago, volcanic emplacements 3.3 to 3.75 billion years ago. Note deposition and infilling basin depression with sedimentary strata.

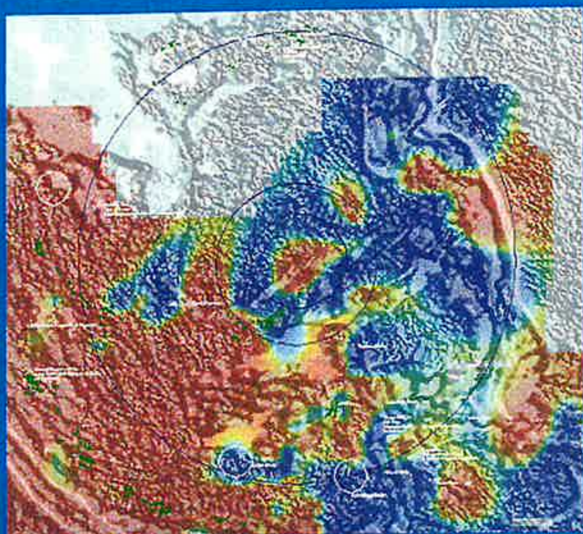
Plate tectonics theory for Earth does not address the existence and affects of massive impacts. Numerous geological phenomena including mantle diapirs, radial intersecting, concentric, and anastomosing fractures and tectonic lines, vortex structures, dike swarms, mantle hotspots - all are unaccounted for. Because the current renaissance of space exploration post-dates the development of plate tectonics theory, naturally plate tectonics theory could not and does not account for the observed crater tectonics evolutions of the surfaces of the Moon, or Mars, or Venus. Nor have observations of crater tectonics active in our solar system been applied to update plate tectonics theories for Earth. On the Moon and Mars, our analogues in space, Copernican-scale impacts have convincingly formed nearly all basins, and the same formative events have in addition perturbed the respective mantles and initiated the majority of global volcanism. On these celestial bodies, Copernican events have perturbed their mantles, have initiated convection cells, reverberations, and resonations that persisted at least hundreds of millions of years. If our neighbours in space are our analogues for Earth, why do we complicate geologic features and fabrics on Earth by pragmatically imposing plate-like polygonal symmetries rather than radial, circular symmetries?

Crater tectonics evolution of Australasia

Occam's Razor states that the simplest explanation is closest to the truth. The observation that South America and Africa resemble puzzle pieces is the simplest evidence for continental drift. In crater tectonics, the simplest evidence is circular, radial morphology. In the Australasian Theatre, along the south-west arc of the proposed Copernican crater lies the volcanic arc and chain of Sumatra-Java-Bali Islands. The north-east volcanic arc occurs in the Philippines. Similar volcanic arcs have been associated with Martian impact basins, wherein both global volcanic arcs, and local arcs, are governed by fractures radial to, and encircling, major impact sites (Schneid, 1989).

The proposed South China Sea Copernican consists of a 540-kilometre diameter bathymetric depression. The centre of this feature exhibits an elevated geothermal gradient, and is surrounded by rings of alternately higher and lower geothermal gradients. The presence of high-temperature hydrothermal systems associated with the central uplifts of impact craters is reported at the Manson crater, Iowa, and at the Russian Puchezh-Katunki crater (Crossey and others, 1994).

The central dome of higher heat flow anomaly in the South China Sea coincides with a calculated depth to basement based on CCOP Magnetics of 9 kilometres (Bird & Gibson, 1998), while surrounding that in circular fashion and passing through the Palawan Islands is a zone of 5.0 to 7.0 kilometres depth to basement. Magnetics and Gravity based interpretations of tectonic features, faults and fracture zones exhibit decidedly radiating fabrics emanating from the South China Sea Anomaly. Depocentres, structures, orogenic belts and oil and gas production in the area - all have elemental geometries that either radiate or encircle the scar. The upwelling vortex identified as the Indonesian archipelago, based upon GEOSAT satellite altimetry data, bathymetry, earthquake and volcanic data (Smoot & Leybourne, 1997) also coincides with the scar.

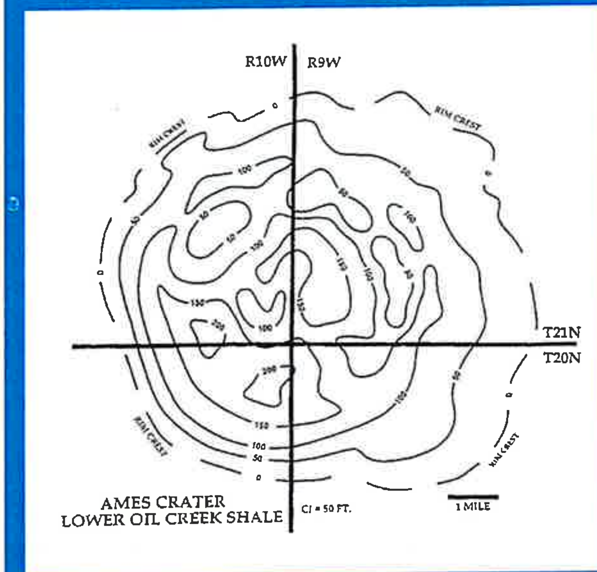


Fused image integrating satellite gravity shaded relief grey-scale and geothermal gradient colour scale. Geothermal gradient shows outer ring of higher gradient surrounding ring of lower gradient (blues), which encircles the centre of the South China Sea scar.

Structural fabric and source rock distribution

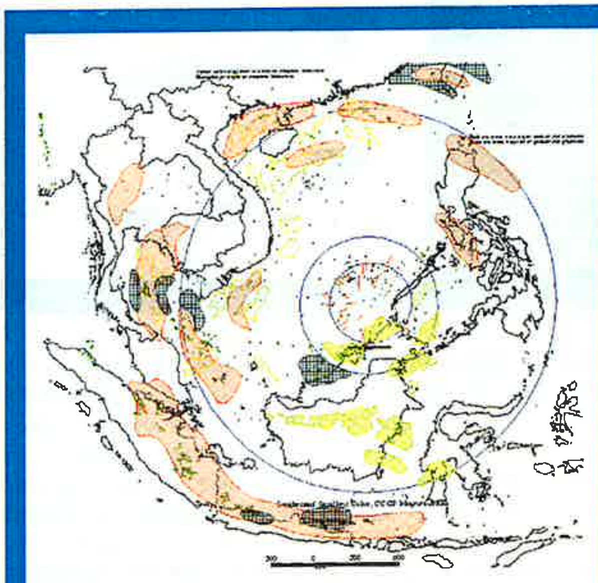
Distributed concentrically about the South China Sea scar are numerous potential secondary craters that would have formed during excavation and fallout from the main impact event. The Salayar, Barito, Bukit Paloh, Sarawak and Vietnam anomalies lie along a common radius from the proposed ground zero in the South China Sea. Also distributed concentrically are rare occurrences of oil and gas production from fractured granites, gneisses, volcanics and ophiolites, on the island of Java, offshore Vietnam and Sulawesi. Known crater tectonic elements, such as encircling rim anticlines and synclines, radial fractures, thrust faults, melange, normally faulted terraces, volcanism, deposition, central peaks, and multiple rings, all are present in this theatre, albeit their genesis having historically been of contentious debate.

If the paleo-bathymetry/topography was controlled by the morphologic elements of a multi-ringed impact basin, then locally thick, organic-rich sediments could have been deposited. Using the oil-productive Ames Oklahoma impact crater analogy (figure 4), whereby the crater depression and ring synclines focused deposition of the rich lower Oil Creek Shale (Castano and others, 1997), one might predict that source rock focusing may have occurred in the South-eastern Asia Theatre. Located landward of the outer impact ring, the outer arcs Sumatra-Java-Bali, the Pearl River Mouth Basins, and offshore Vietnam and Thailand, all owe their petroleum riches to lacustrine source rocks. The next inner ring of this proposed multi-ringed basin has focused, first, lacustrine sediments radially outward from the rings' anticlinal crests and second, on the inside of the crests' normal faulted terraces, major deltaic source rock depositions.



Isopach map of the Lower Oil Creek Shale source rock interval that charged the 50+ MMBO Ames Crater Oil Field, Major County, Oklahoma (from Castano and others, 1997).

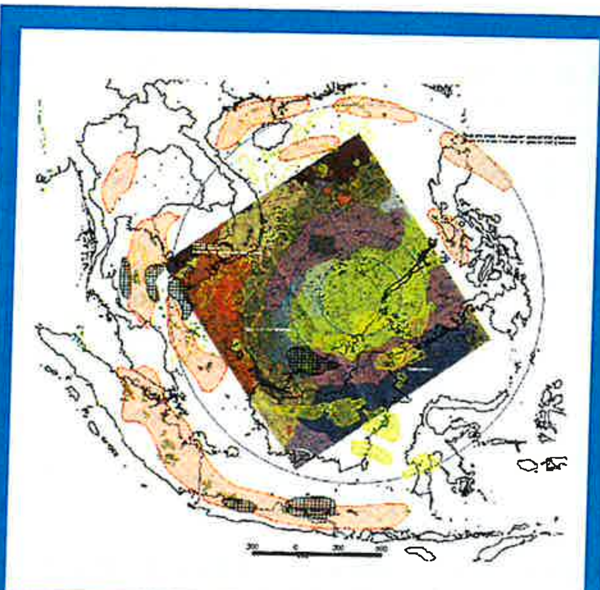
Three-hundred and fifty crude oil samples analysed to determine compositionally distinct oil families in these Circum-Pacific Basins indicate that four distinct paleo-environmental conditions existed: terrigenous, lacustrine, deltaic, and marine. Utilising this data (from Schiefelbein and others, 1997), and grid krieging this data with satellite gravity, magnetics, geothermal gradient, cross section, potential fields modelling, and other data and in the context of this area having been imprinted by the fabric of a Copernican impact crater, the petroleum systems map in a curiously concentric series of belts (figure 5). Well outside the impact basin, one would have to surmise older Mesozoic source rocks, consistent with those found at Irian Jaya and the north-west shelf of Australia.



Petroleum source rock systems of Southeast Asia. Red cross-hatched areas are lacustrine and resinitic, black cross-hatched areas are terrestrial and mixed algal/resin, and yellow hatched areas are deltaic source rock belts. Also plotted are oil and gas fields, tectonic elements radiating from the crater centre, coastlines, depocentres, and control points for depth to magnetic basement determinations.

Conclusions

Earth has not been immune to Copernican-scale impact cataclysms. It is proposed that the event responsible for deposition of the Australasian Tektite Field and for imposing the tectonic fabric in Southeast Asia offshore is the South China Sea Scar. This impact feature imposes its geothermal, gravity, magnetics, tectonic and orogenic fingerprint on the region. Because significant oil and gas reserves are known to exist both onshore and offshore within the theatre affected by this impact, someday the data required to prove this genesis, such as the presence and distribution of impact breccia, shock quartz, ejecta, secondary craters, and shatter cones, may be available. Until then it is with the watchful eye of the integrator, and time, that evidence unfolds to refute or confirm its existence.



Comparison of Hellas Basin, Mars, and the South China Sea Scar—both at the same scale. Green are oil and gas fields.

References

1. Bird, D., and Gibson, D., 1998, *Regional Gravity & Magnetic Interpretation South China Sea and Vicinity*, A proprietary, non-exclusive interpretation by Bird Geophysical and Gibson Consulting, Houston.
2. Buchanan, P. L., Koeber l, C., and Reid, A.M., 1998, *Impact into unconsolidated, water-rich sediments at the Marquez Dome, Texas*, in Meteoritics & Planetary Science 33, pp. 1053-64.
3. Buthman, D. B., 1998, *Crater tectonics' role in exploration: how asteroid and comet strikes have shaped Earth*, Offshore Magazine, July 1998, p. 108-112.
4. Butler, M. D., 1994, An introduction to the meteor impact process, in The Leading Edge, March 1994, pp. 188-90.
5. Castano, J. R., Clement, J. H., Kuykendall, M. D., and Sharpton, V. L., 1997, *Source-rock potential of impact craters*, in Johnson, K. S., and Campbell, J. A. (eds.), Ames structure in north-west Oklahoma and similar features: origin and petroleum production (1995 symposium): Oklahoma Geological Survey Circular 100, p. 100-103.
6. Craddock, R. A., 1998, *Geologic history of Isidis Planitia and Syrtis Major Planum, Mars*, in Lunar and Planetary Science XXV abstracts of papers submitted to the twenty-fifth lunar and planetary science conference, March 14-18, 1994, Part 1, pp. 291-2, Houston.
7. Crossey, L. J., Kudo, A.M., and McCarville, P., *Post-impact hydrothermal systems: Manson impact structure, Manson, Iowa*, in Lunar and Planetary Science XXV abstracts of papers submitted to the twenty-fifth lunar and planetary science conference, March 14-18, 1994, Part 1, pp. 299-300, Houston.
8. L.P.I. Lunar and Planetary Institute, Houston, Texas
9. Negi, J. G., Agrawal, P. K., Pandey, O. P., and Singh, A. P., 1993, *A possible K-T boundary bolide impact site offshore near Bombay and triggering of rapid Deccan volcanism*, in Physics of the Earth & Planetary Interiors, 76 (3-4), pp 189-97.
10. Poag, C. W., 1998: Backyard Bolides: *Finding a Buried Impact Crater*, in The Planetary Report, September/October 1998.
11. Schneid, B. D., and Greeley, R., 1989, *Global associations of volcanic vents to fractures radial to large impact basins on Mars*, in Holt, H., (ed), NASA Technical Memorandum 4210: Reports on Planetary Geology and Geophysics Program—1989, pp 444-5, Washington, D.C.
12. Sharpton, V. L., and Marin, L. E., 1997, *The Chicxulub Impact Basin, Yucatan, Mexico*, in Johnson, K. S.; and Campbell, J. A. (eds.), Ames structure in north-west Oklahoma and similar features: origin and petroleum production (1995 symposium): Oklahoma Geological Survey Circular 100, p. 277.
13. Smoot, N. Christian, and Leybourne, Bruce A., 1997. *Vortex Structures and the World-Encircling Vortex Street: Case Study of the South Adriatic Basin*, in Marine Technology Society Journal, v. 31, n. 2, Summer 1997.
14. Schiefelbein, C. F., Zumberge, J. E., Brown, S. W., 1997, *Petroleum Systems in the Far East*, in J. V. C. Howes and R. A. Noble (eds), Proceedings IPA Petroleum Systems of SE Asia and Australasia Conference, Jakarta, Indonesia, May, 1997, Indonesian Petroleum Association, Jakarta, pp. 101-113.
15. Spudis, P. D., and Adkins, C.D., 1998, *Morphometry of basins on the moon: new results from Clementine laser altimetry*, in Lunar and Planetary Science XXVII abstracts of papers submitted to the twenty-seventh lunar and planetary science conference, March 18-22, 1996, Part 3, pp. 1253-4, Houston.

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