Chesapeake Invader: Discovering America's Giant Meteorite Crater. C. Wylie Poag, Princeton University Press, Princeton, New Jersey, USA. 1999. pp. 183. Price: US $24.95.

Though earth has been bombarded since early in its history by meteorites and asteroids of varying sizes, recognition of their impact craters has been made difficult because of their obliteration by weathering processes or they happen to be covered by water (if the impact was over the sea) or by later-day sediments. Until about two decades ago features marking these craters were missed because surveys were not aimed towards their identity or the surveyors did not have the expertise in the specialized discipline of impact geology. Following the publication of the meteorite impact hypothesis in 1980, by Alvarez *et al.* in *Science*, to explain the extinction of dinosaurs and other life-forms, the general awareness of the geological community, who were always looking for earth-bound causes to explain such mass extinctions, was awakened to possibilities from outer space also. Further, the spectacular live impacts of the disintegrated Shoemaker–Levy 9 (SL-9) comet that crashed on Jupiter in July 1996, spurred geologists to reinvestigate some of the enigmatic crater-like features on earth. For example, some of the craters aligned along the 700 km length in Kansas, Missouri and Illinois in USA earlier thought to be volcanic in origin, turned out to be multiple impact craters, like the ones created by SL-9 on Jupiter. About 150 craters on earth of undoubted meteoritic origin are on record today, the oldest among them being 1685 m.y. old Teague crater (30 km diameter) in western Australia. A few of these were discoveries resulting from pictures taken by the orbiting satellites.

Chesapeake Bay forming the eastern coast of Virginia, USA, was hit by two massive meteorites during late Eocene, some 35 m.y. ago, but their impact craters lay hidden under the seabed covered by thick sediments. Wylie Poag, the author of the book under review, has sifted through records of past geological work in this region, re-examined volumes of seismic data, and has narrated here how the undersea craters came to be recognized. For the benefit of non-specialist readers, he has devoted a few chapters explaining aspects of geological rock formations of the eastern US coast, evolution and extinction of life on earth, inferences that one can derive from study of fossils, and other topics pertinent to the understanding of impact geology. He has also described the basic principles about some of the field and oceanographic techniques employed in his studies.

The scenario about 35 m.y. ago in this part of eastern USA was different from what it is today. The Atlantic coast had then rimmed the flanks of Appalachian Mountains, about 200 miles further inland, covering the present-day locations of Richmond, Washington DC and Baltimore. Piecing together data arising from seismic, hydrogeologic, palaeontologic and geochemical and other investigations, Poag could prove that the Chesapeake Bay area had indeed been invaded by two meteorites during late Eocene period. Early suspicion about the possibility of meteorite impact here arose while trying to explain a peculiar rock formation occurring at depths which came to notice while examining the solid drill cores. This drilling programme was undertaken to find new sources for freshwater along the Virginia coastal formation called Exmore Beds. The peculiar rock assemblage revealed in the cores is actually a thick zone of breccia, better known as 'debrites', which usually form due to down-slope accumulation of material from the top. This zone carried assorted rocks of different ages along with a mixed population of marine as well as freshwater fossils. Forams and nannofossils from the Cretaceous period (120 m.y.) were randomly mixed up with Eocene fossils (40 m.y.) and age-wise succession, which is the normal mode of field occurrence, was absent. Such a jumble of rocks of differing lithology and age and fossils from diverse environment and time was enigmatic to geologists as they can be produced only through powerful external agencies. Thanks to general awakening among earth scientists to potentialities from cosmic collisions, the needle of suspicion gradually veered towards an extraterrestrial agent such as an asteroid or meteorite impacting here.

Numerous additional evidences conforming the meteorite connection came from more extensive drilling carried out in connection with oceanographic studies about the US continental margin and its evolution. In particular, the cores from undersea continuation of Eocene Exmore Beds at the site DSDP-612 undertaken by JOIDES *Resolution*, contained 'tektites' (impact-heat produced melt-glass), shocked and high pressure quartz like stishovite and coesite, all unmistakable evidences proving the impact. Interestingly, the geochemistry of these tektites matched well with that of sediments derived from the Appalachian Mountain, thus pointing to their provenance. Apart from these, the seismic profiles of the Bay region indicated a considerable disturbance to the Eocene strata at an undersea canyon location known as Toms Canyon, 16 miles north of this DSDP-site 612. A roughly triangular crater-like structure could be clearly delineated here with its base towards north-east, apparently caused by a meteorite impacting at a low angle. This crater lay covered by 3000 feet of Eocene sedimentary rocks and measured 12 miles in length and 8 miles in width with the floor of the crater 1000 feet below the rim. But the location of this site some 16 miles away from the Exmore Beds where impact-caused assortment of fossils and rocks were first observed perplexed the author for an explanation. He initially proposed that the huge tsunami wave generated in the wake of impact over Toms Canyon seabed must have transported the materials, but skeptics doubted such a transport over 16 miles. Further, they pointed to absence of tektites and tsunami deposits closer to Toms Canyon area.

Not convinced by his own tsunami hypothesis, the author searched for a better collection of closely gridded seismic data of the Bay area, which he could obtain from an oil exploration company. These new data of the lower Bay revealed a huge mile-deep hole that must have been produced by a meteorite at least 2 or 3 miles in diameter, beneath the town of Cape Charles on the tip of Delmarva Peninsula. The impacting body had penetrated not only the unconsolidated sediments but also the hard granitic basement carving a wide annular trough. The author concluded that the Exmore Bed of breccia was part of an immense deposit 'generated directly

by the impact of an enormous meteorite that had struck right in the very center of the Virginia study area', while the shocked quartz, feldspar, partial melting of other minerals in the basement granite in Toms Canyon area were due to crash of another meteorite at about the same time. Curious to know if there had been more such meteorite impacts elsewhere around this period, he found that the well-known Popigai crater in northern Siberia was also carved at about the same time. Meteorite impacts in the past have been followed by periods of climatic changes and episodes of extinction of life. Geologists have in fact, recognized five such major and a few minor episodes in the earth's history. But this triple impact over the Chesapeake Bay, Toms Canyon and Popigai during Eocene was followed only by climatic changes. The mass extinction of life came about much later, during the succeeding Oligocene period and Poag feels that this was due to delayed 'biotic response to complex combination of triggering mechanisms'. He envisaged the following sequence – a pulse of greenhouse warming after the triple impact in the midst of global cooling trend → dissipation of heat and acceleration of Antarctic ice growth → drop in global temperature → extinction of life or their reduction in distribution during Oligocene.

Poag thereafter examines some of the consequences of the cosmic collision on the geology of the Chesapeake region. The crater produced by the meteorites was instrumental in the preservation of certain clay beds when the Atlantic Ocean receded from Appalachian Mountain flanks during Oligocene. These collisions had uplifted certain beds, which today form a part of the crater rim and had induced differential sinking of land lying over the breccia zone of the crater. They had also influenced the course of rivers in the region and made them converge owing to land subsidence. The quality of ground-water was affected as the crater breccia region served as a brine reservoir. Impact generated subsurface features that can trigger land movements and seismic events exposed residences and installations over the breccia zone to potential risks of collapse and other damaging effects. Though the seismic susceptibility of the region is otherwise negligible, Poag suggests carrying out close gridded seismic survey to assess such risks. Among the positive aspects of meteorite impacts, he lists a number of economic minerals associated with or influenced by them such as redistribution of already existing minerals, or their concentration by the heat of impact. The craters also served in some cases as water reservoirs or for accumulation of oil, gas, iron and uranium and Poag is optimistic that they can be potential sites for disposal of low level hazardous industrial wastes. This book carries convincing arguments establishing meteorite impacts along the eastern coast of USA and it is hoped that soon data on radioactive dating and characteristic geochemical anomalies associated with meteorite impacts would also be available on suitable samples.

A. V. SANKARAN

10, P&T Colony, I Cross,
II Block, RT Nagar,
Bangalore 560 032, India

Interrelationship Between Insects and Plants. Pierre Jolivet. CRC Press, Boca Raton, USA. 1998. pp. 309. Price: US $59.95/DM 108.

Interrelationships between insects and plants have been extensively studied during the last two decades, particularly in terms of their defence mechanisms. The book under review is different in the sense that it deals with insect food selection and behaviour *vis-à-vis* the plants. The speciality of the book lies particularly in the inclusion of carnivorous and myrmecephilous plants and also the aspects of pollination showing harmonic relations between pollinators and blossoms.

This single-author compilation is a testimony to the expansion of knowledge with respect to plant-feeding insects and arthropods of the geological past and those of the 20th century polyphagous insects.

The first of the 15 chapters reviews simply the plant–arthropod relationships describing sapsuckers, fruit eating, nectar eating, pollen and spore eating, chewing and carnivorous behaviour of insects. The second and third chapters deal with plant-feeding insects of the past and the present, and also explain the status of mono-, oligo-, poly-, panto- and xenophagy in insects. These chapters also emphasize the mechanisms of plant resistance to insect pests with examples such as the American grapevine and resistant varieties of rice.

The relationship between insects and microbials like fungi makes up the fourth chapter. A close association between ants and termites and their respective fungi has been explained in a very explicit manner to bring forth a more or less perfect symbiotic relationship and how the production of antibiotics helps in the growth of fungi which are useful to the host.

Chapter five on physiology of food selection provides evidence that chemical composition of leaves varies with the age of the plant and variation in plant chemistry. This explains in part at least the local or seasonal behaviour of insects and also the ability of certain plants to resist these insect species. On the whole it is clear that food procurement by insects is related to visual or chemical selection. However, in the case of carnivorous or protocarnivorous plants belonging to 8 families, procurement of food involves the attraction, retention, trapping, killing and digestion of insects with the help of their modified structures or by using excreta and cadavers abandoned by insects (like ants). Such a phenomenon in various species has been comprehensively dealt with in chapter six.

Chapters seven and eight deal with symbiotic association (myrmecophily) between plants and ants or between insects and ants of epizoic symbiosis, i.e. external growth of cryptogam on the backs of insects in a humid environment.

Chapters on galls and mines, insect mimicry and homochrony in relation to plants are interesting. In fact, chemical mimicry can be one of the leading tools in the development of a control method in insect pest management. This phenomenon should have been discussed in more detail.

Pollination and coevolution between insects and plants are good inclusions in this book and the author has done well