ing common nowadays. In 1999, the city government ordered all vehicles to convert to liquefied petroleum gas and natural gas. By 2002, Beijing had the largest fleet of natural gas buses in the world – a total of 1630 vehicles. As a matter of fact, India attempted to enforce this ahead of China, when India's Supreme Court issued a ruling in 1998 requiring all the city buses in New Delhi to be run on compressed natural gas by 31 March 2001. But only 200 buses were ready by the deadline. Public protests, riots and commuter chaos forced a gradual phase out of the existing 12,000 diesel bus fleet. New Delhi's airborne particulate matter has been registered at levels over ten times of the legal limit and automobiles have been blamed as the prime source of pollution, with more than three million cars, trucks, buses, taxis, and rickshaws often crowding the city streets. India's increasing urban pollution problems are not due to absence of sound environmental policies but due to the lack of enforcement at the local level. Therefore, sweeping measures and public awareness are certainly necessary to tackle pollution in major cities across India. The strategies that are being tested out in the neighbouring China, including higher government spending to tackle pollution, could be pursued in India to combat the choking pollution hazards of the 21st century.

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RESEARCH NEWS

Recent revisions to the geologic time scale

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Dividing 4.5 billion years (b.y.) of earth's geological history into relevant time intervals having global reference or correlation potential has continued to remain an unsettled issue since the times of early geologists like James Hutton (1795) and Charles Lyell (1800). Quite a few methods to achieve geologic time units are on record and over the years a maze of terms have come into use to qualify a specific geologic time, some based on rock successions or stratigraphy (e.g. systems, series, stages), and others based on incidence of important events (e.g. eons, eras, periods, epochs, ages). Also, ambiguous prefixes were used like early-, mid- or late-, or upper-, or lower-, to describe geological intervals. Yet, the divisions marking the stages in the earth's history remained unsatisfactory. For example, the relatively small Phanerozoic time period, covering the last ~ 570 million years, is well divided into 3 major divisions and 16 sub-divisions made easy by abundant paleontological data available. But the vast Precambrian, stretching for nearly 4 billion years, is divided into only two major divisions – Proterozoic and Archaean, a deficiency, neglected till late twentieth century, and surprisingly incomplete even today.

The setting up of the International Union of Geological Congress (IUGS) in the 1960s, saw the commencement of global efforts to correct the distorted state of geologic time divisions. A network of laboratories using uniform investigative procedures took up the task of providing geological data having good acceptability in all aspects. The International Commission on Stratigraphy (ICS) that was set up subsequently organized a few subcommissions which were entrusted with the task of compiling and maintaining stratigraphical database to unify regional nomenclature, update results from new multidisciplinary methods and also to define and classify the terminologies. As a result, the geologic time scale gradually began to present more relevant and reliable divisions of globally applicable stratigraphic units. The revisions put out in the years 1982, 1989 and 2000 are notable, in this connection, though they are not totally complete or perfect[1–3].

In the last two decades alone, developments in field and laboratory techniques, advances in radiogenic and stable isotope studies, improved assessment of fossil records, use of the evidences of earth's magnetic reversals and climatic cycles preserved in sedimentary beds for dating purposes, have all enhanced the quality of data and contributed much to fine-tune the international chrono-stratigraphical scale, introduce new subdivisions and to fix geologic stage boundaries. Synthesizing the major contributions arising from these new approaches, the ICS-Meeting in 2004, headed by F. M. Gradstein, University of Oslo, along with 38 other specialists, discussed the revisions emerging from the fresh data and brought out the latest version of the Geologic Time Scale[4,5], GTS 2004 (Figure 1).

In their revisions to the GTS, Gradstein's team selected from among several of the methods available to construct the geologic time scale, the ones that could provide reliable information for the construction. For example, new seafloor spreading data calibrated through combined application of geomagnetic polarity time scale (GPTS) and $^{40}Ar/^{39}Ar$ dating were applied to fix some of the time boundaries, e.g. Jurassic – Cretaceous, Cretaceous – Cenozoic. Likewise, astronomical tuning of sedimentary cycles influenced by earth's changes in its eccentricity, obliquity and precession (orbital tuning), considered accurate to within ~ 20 K yr, were used to fix Mesozoic subdivisions (Cretaceous,

Eon	Era	Period	Ma
PHANEROZOIC	Cenozoic	Neogene	23.03–0
		Paleogene	65.5–23.03
	Mesozoic	Cretaceous	145.5–65.5
		Jurassic	199.6–145.5
		Triassic	251.0–199.6
	Paleozoic	Permian	299.0–251.0
		Carboniferous	359.2–299.0
		Devonian	416.0–359.2
		Silurian	443.7–416.0
		Ordovician	488.3–443.7
		Cambrian	542.0–488.3
PROTEROZOIC	Neoproterozoic	Ediacaran	650–542.0
		Cryogenian	850–650
		Tonian	1000–850
	Mesoproterozoic (Riphean)	Stenian	1200–1000
		Ectasian	1400–1200
		Calymmian	1600–1400
	Paleoproterozoic	Statherian	1800–1600
		Orosirian	2050–1800
		Rhyacian	2300–2050
		Siderian	2500–2300
ARCHEAN	Neoarchaean	Divisions to be ratified by ICS	2800–2500
	Mesoarchaean		3200–2800
	Paleoarchaean (Isuan)		3600–3200
	Eoarchaean		base not defined - 3600
HADEAN		Formalized time scale yet to be made	

Figure 1. A condensed version of the geologic time scale – 2004 (adapted from ref. 5).

Jurassic, Triassic) and also the much younger 0–23 million year period. Highly precise radiometric dates by isotope dilution mass spectrometric (TIMS) methods (U/Pb), $^{40}Ar/^{39}Ar$ radiometric ages monitored with new improved standards and published data obtained from recent SHRIMP (U/Pb) methods were employed. These conferred better reliability for several of the stratigraphic intervals between Cambrian – Triassic – Cretaceous periods, hitherto divided mostly on basis of paleontological or tectonic events. Geo-mathematical and statistical curve fitting methods were some of the other techniques employed in the evaluation of available fossil data, radiometric ages as well as seafloor spreading-rates during Triassic – Jurassic and Cretaceous – Cenozoic gaps.

The GTS-2004, which embodies significant changes, will be defined at its base by a Global Stratotype Section and Point (GSSP) having global correlation potential or Global Standard Stratigraphic Age (GSSA)[6,7]. Nearly 50 GSSPs and 10 GSSA have now been approved. While the term Precambrian will still be used to group rocks older than the Cambrian, it does not form a chronostratigraphic or geochronologic unit of the GTS–2004. The Neoproterozoic span (1000–542 Ma) has now a new sub-division called the Ediacaran System/Period, defined with a GSSP in South Australia (Flinders Range). The base of this period is provisionally fixed at 635.5 ± 1.2 Ma, noted for the beginning of the diversification of animal life recorded globally by the occurrence of ediacaran fauna. This period begins at the end of the well-known global glaciation (Marinoan glaciation) around 630–620 Ma, the end of which is marked by cap carbonates (620 Ma).

The bases of Paleozoic, Mesozoic and Cenozoic are fixed with analytically precise ages at 542 ± 1.0 Ma, 251 ± 0.4 Ma and 65.6 ± 0.3 Ma. The new scale does not favour usage of the terms Tertiary and Quaternary System/Periods and instead recommends the term Neogene embracing Miocene, Oligocene, Pliocene (previously part of Tertiary period) and Pleistocene and Holocene (previously Quaternary). For example, Cretaceous–Tertiary boundary will be hereafter referred to as Cretaceous–Paleogene. However, there has been a strong move to retain the use of the term Quaternary, by defining it as a subsystem of Neogene, thus extending the base of Quaternary to 2.6 Ma to encompass Holocene and Pleistocene and the late part of Pliocene, the time span when earth's climate was much influenced by bi-polar glaciation and by the first appearance of the genus *Homo*[8]. The latter suggestion is being discussed by a task force of the ICS, and presently this is not yet a formal chronostratigraphic unit.

Though tremendous efforts have gone behind the making of GTS-2004, the building up of an ideal scale, which will have consensus with entire geologic community, has a long way to go. Another revision is due when the 33rd International Geological Congress meets in the year 2008. It is expected that this meet will address new revisions and hopefully be able to solve many of the unanswered issues like defining some of classic boundaries such as the Devonian/Carboniferous, Permian/Triassic, standardizing existing long stages (e.g. Cambrian, Phanerozoic). Approval of the suggested chronometric divisions to the Archean eon into Neoarchaean, Mesoarchaean, Paleoarchaean and Eoarchaean is also awaited. Lastly, it is hoped the meet will also look into dividing the Hadean era, the highly turbulent phase forming earth's earliest part, for which a proper time scale is lacking.

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