MODERN AND ANCIENT TIDES

1926 SEPM
Society for Sedimentary Geology

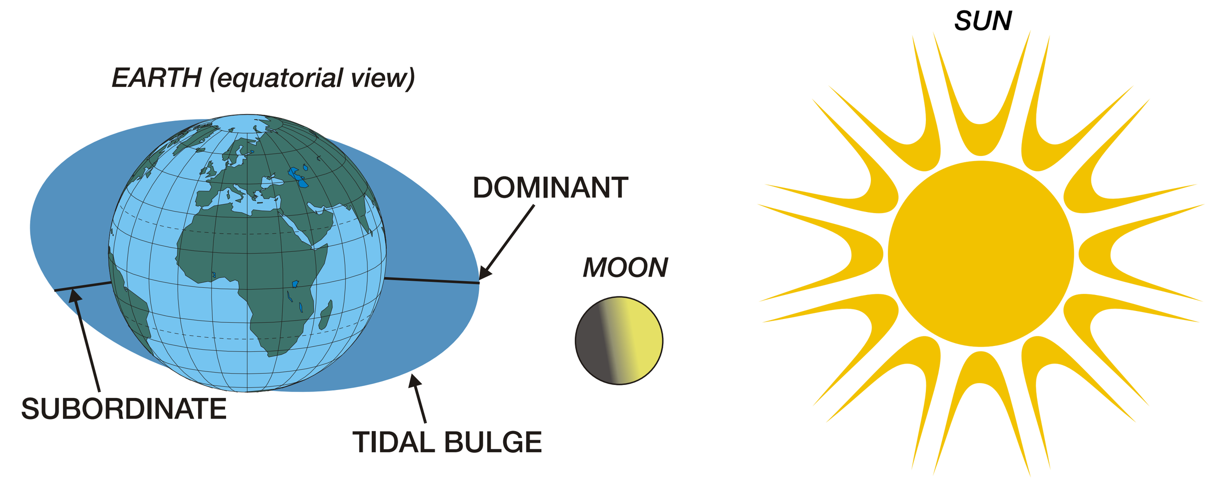
Oceanic tides are capable of generating currents that erode, transport, and deposit sediments. Tidal processes were both significant and widespread throughout much of the Earth's history. These processes can be recorded in small-scale sedimentary structures referred to as "tidal rhythmites" that include thinly layered, fine grained sediments. The tidal influence on the origin of these rhythmites is indicated by the cyclic variations in the thicknesses of successive laminae in response to changing current velocities associated with lunar cycles. The thickness of a lamina is directly and positively related to tidal current strength, which in turn is directly and positively related to the magnitude of the daily rise and fall of the tide (tidal range). Over periods of days, months, or years, changes in tidal current strengths associated with various lunar cycles are mirrored by the change in thicknesses of the vertically stacked laminae.

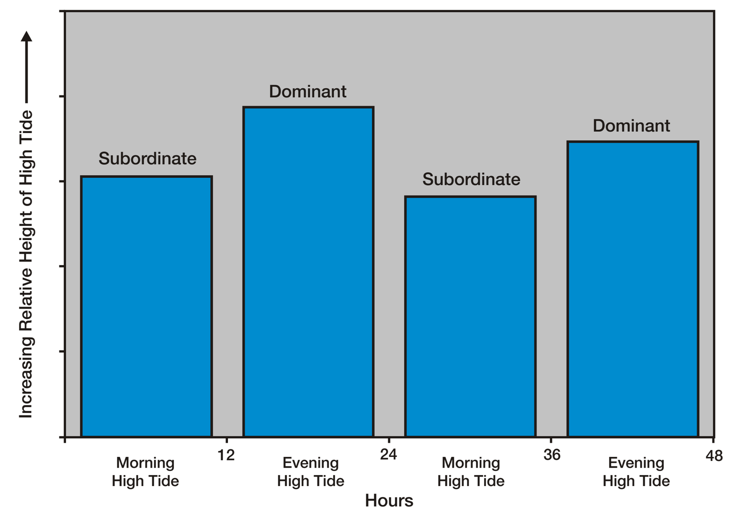
Ancient tidal rhythmites have been found on every continent in the world except Antarctica. In modern environments, tidal rhythmites occur in deposits associated with tide-dominated deltas, tidal embayments, and estuaries. The recognition of ancient tidal rhythmites has important implications for academic and economic reasons. They can be used for reconstructing ancient paleogeographies and paleoclimates, estimating paleotidal ranges, understanding sand transport within tide-dominated basins, and determining lunar-retreat rates through time. The figures below illustrate (from left to right): A diagram and explanation of the tidal theory of the six main governing tidal periodicities that can be detected in rhythmite successions; a bar chart of tidal height data (high tide elevations) from a modern, real-world setting that shows how the astronomical effects are reflected in cyclic changes in daily high tides; a core from an ancient tidal rhythmite succession showing how these cyclic tidal effects might be manifested in a laminated tidal rhythmite; and a bar chart of laminae thicknesses interpreted in the context of the modern tidal cycle.

TIDAL THEORY | MODERN TIDES | ROCK CORE | ANCIENT TIDAL RECORDS FROM CORE

SEMIDIURNAL (12.42 HOURS)

The interaction of tidal forces from the Moon and Sun produce two oceanic bulges on opposite sides of the Earth. The rotation of a point on the Earth through these bulges once a day produces two tides (the semidiurnal tide). Typically, these tides are not equal (termed diurnal inequality), as one is higher (dominant) than the other (subordinate) because of nonparallelism between the Moon's orbital plane and the Earth's equatorial plane. This angular difference is termed lunar declination.





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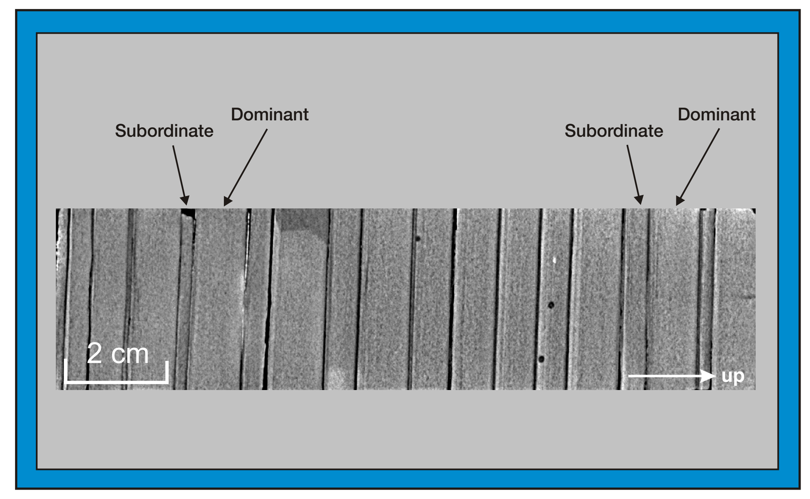

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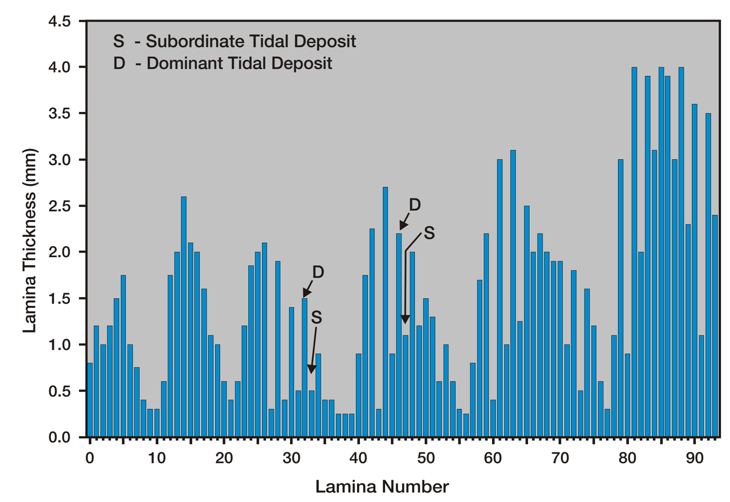
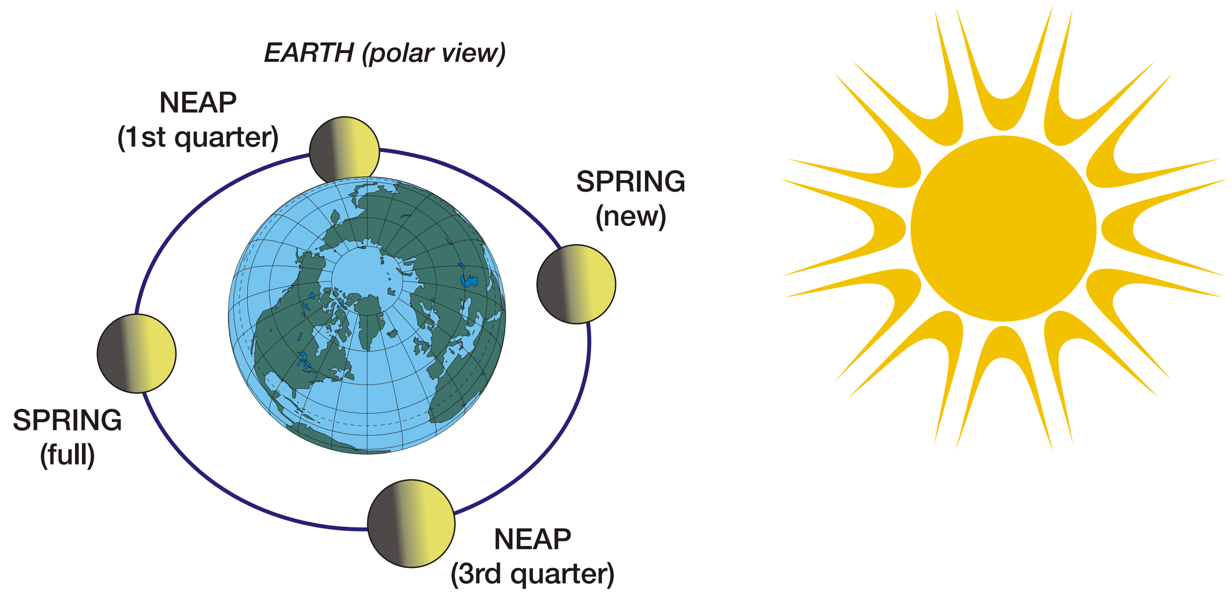
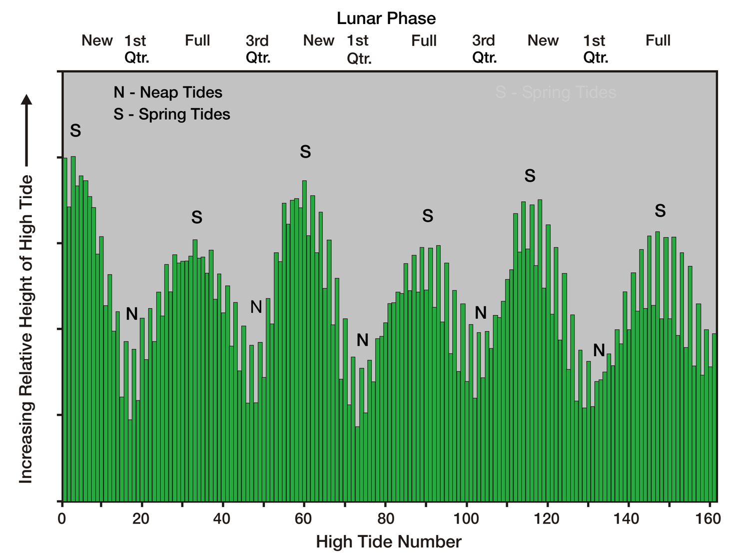


SYNODIC (29.53 DAYS)

Daily high tides are higher when the Earth, Moon, and Sun are nearly aligned (full or new moon) and lower when the Sun and Moon are at right angles to the Earth (1st or 3rd quarter phase). Tides during full or new moon are referred to as spring tides and tides at quarter phases are referred to as neap tides. The neap-spring tidal period is related to the changing phases of the Moon associated with the half-synodic month. The synodic month (new moon to new moon) has a modern period of 29.53 days and contains two neap-spring cycles.





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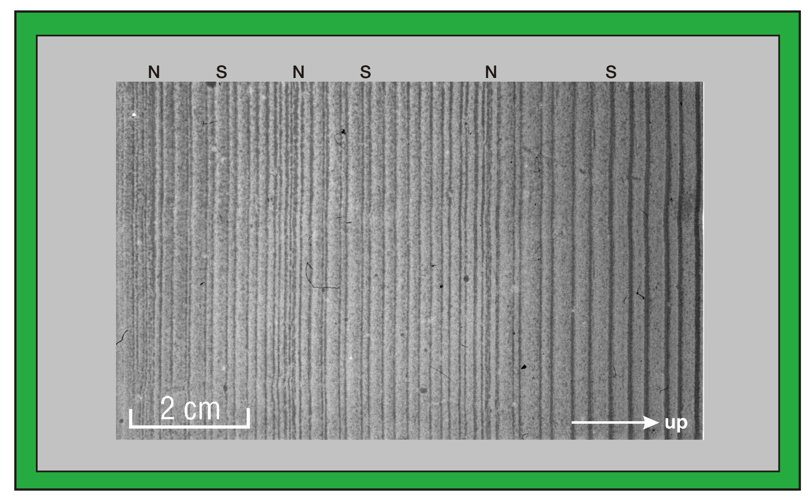

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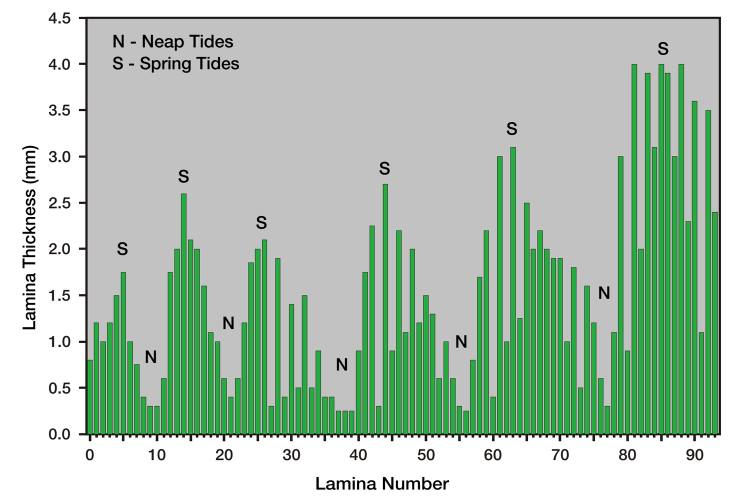
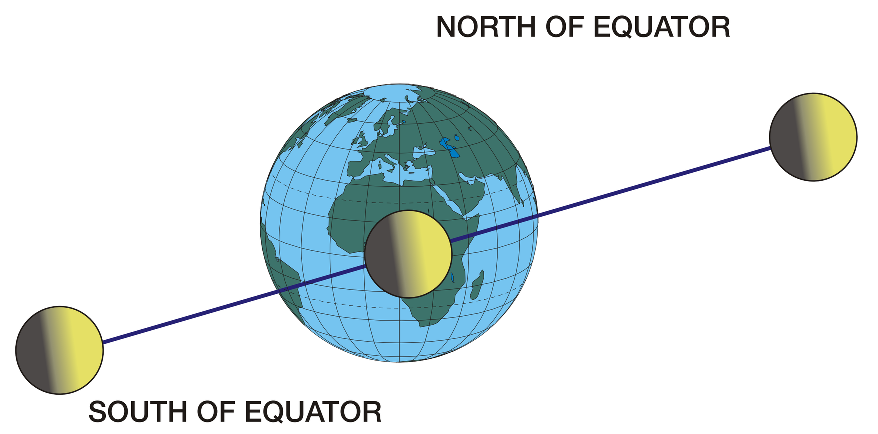
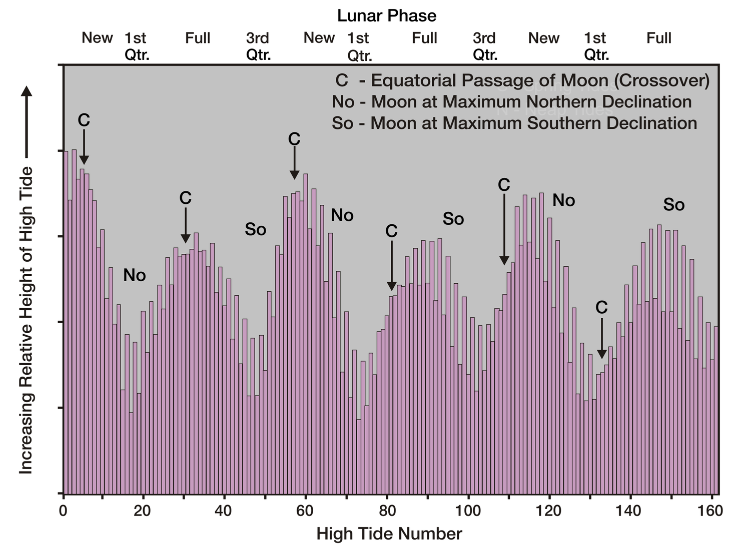


TROPICAL (SEMIDIURNAL - 27.32 DAYS)

The tidal force also depends on the declination of the Moon. The period of the variation in declination is called the tropical month -- the interval of time it takes the Moon to complete one full orbit from its maximum northern declination to its maximum southern declination and then return. The effect of the tropical month in most semidiurnal systems is to cause the diurnal inequality of the tides. Ideally, diurnal inequality is greatest when the Moon is at its maximum declination (as shown at right) and is reduced to zero when the Moon is over the equator, producing a crossover in the modern tidal data (modern tides panel). The current length of the tropical month is 27.32 days (two days shorter than the synodic month -- see synodic row above). Because of this, equatorial passages of the Moon (crossovers) occur faster than the generation of spring tides as indicated by the modern and rock tide data.





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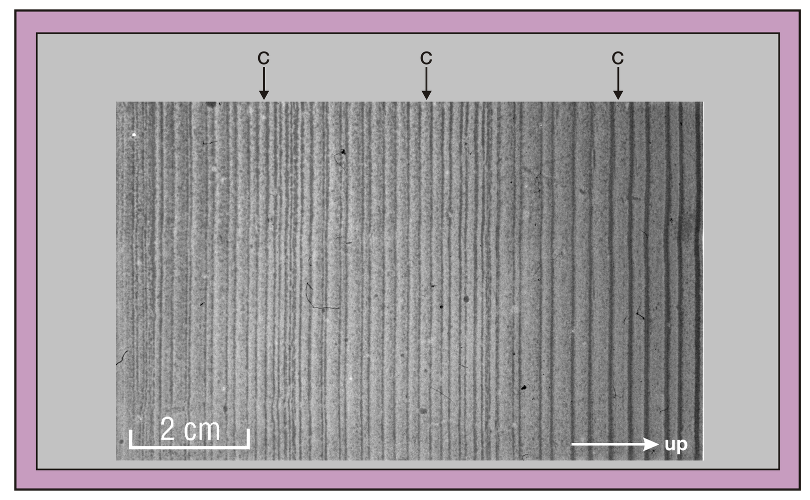

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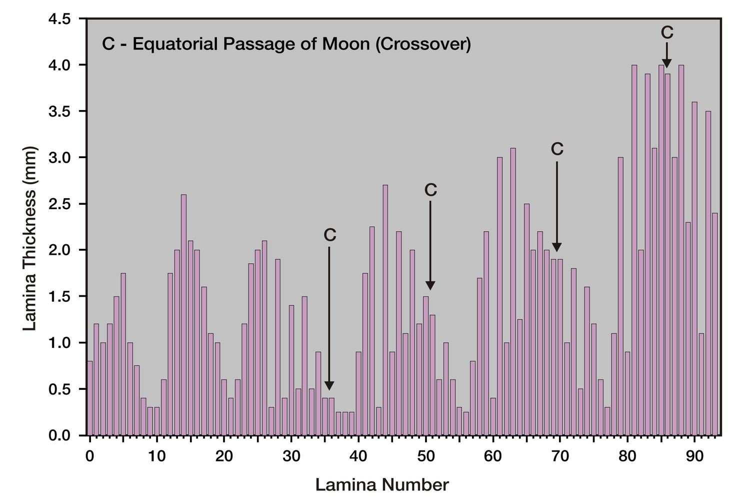
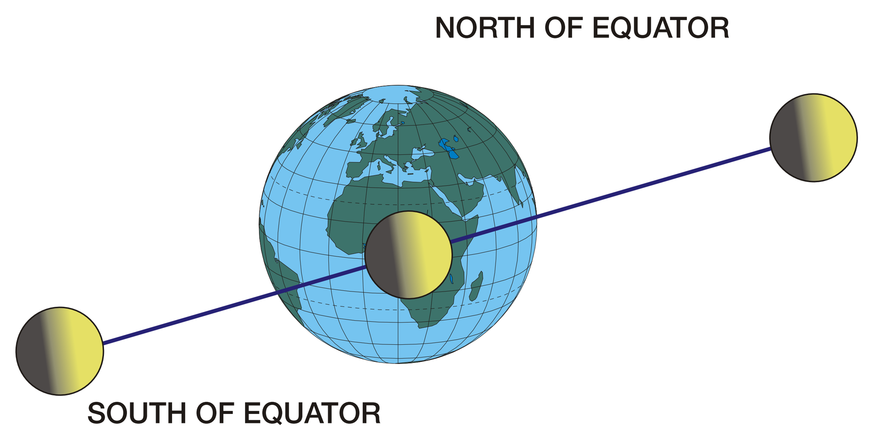
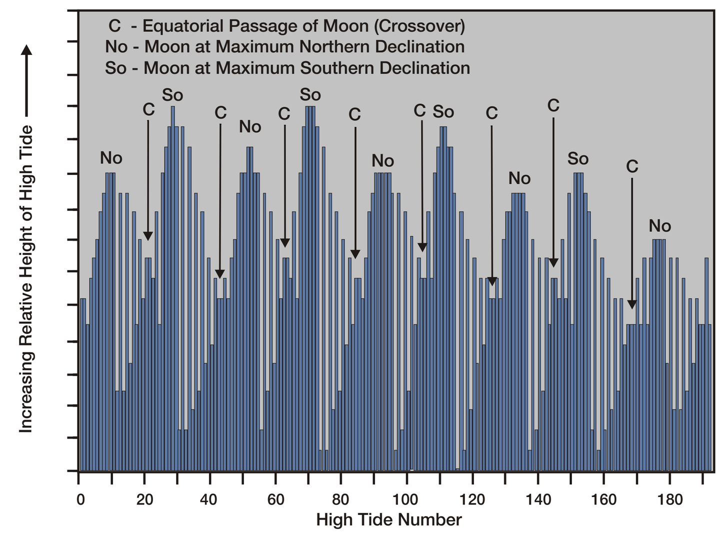


TROPICAL (DIURNAL - 27.32 DAYS)

In many dominantly diurnal systems (primarily one tide per day), the tropical period described above is responsible for generating neap-spring cycles. In contrast to the synodic system, tides in a tropical system behave as though the Sun's gravitational effects are dampened. In such cases, the dominant tidal force depends on the declination of the Moon relative to the Earth's equator with the force being greatest when the Moon is most directly over the site in question. In these systems, the predicted and ancient tide data reveal that equatorial passages of the Moon (crossovers) occur in phase with the generation of neap-spring tides, in contrast to the variable relationship shown in the tropical (semidiurnal) row above.





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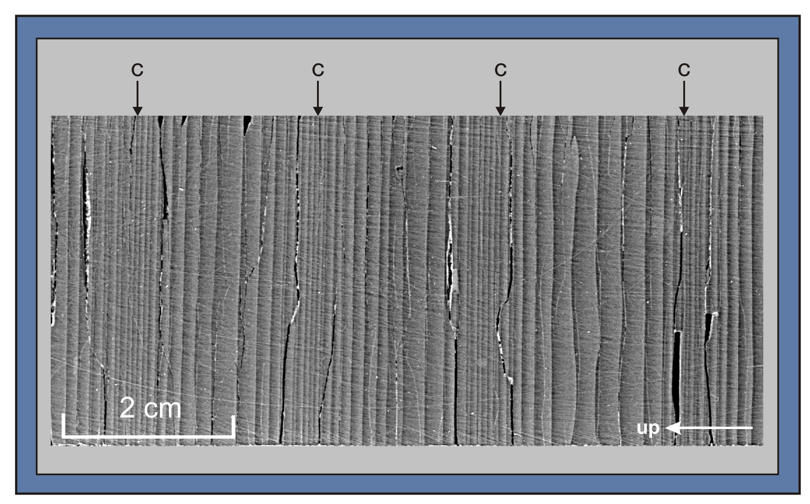

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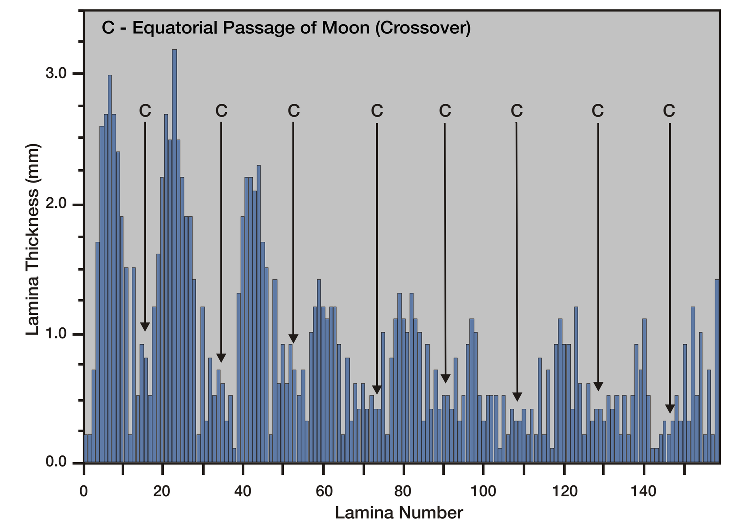
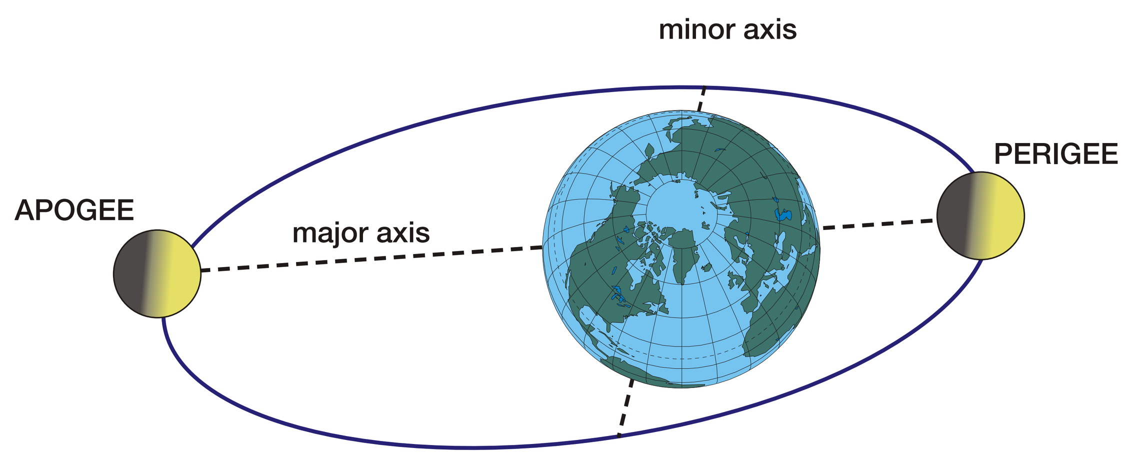
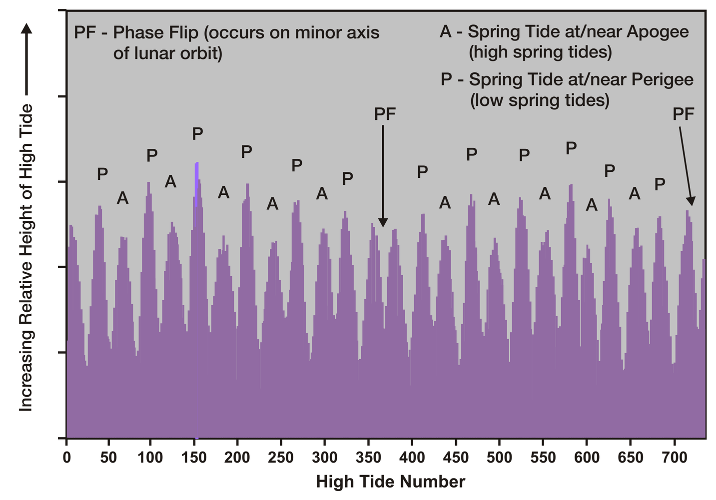


ANOMALISTIC (27.55 DAYS)

Another tidal effect arises from the changing distance of the Moon relative to the Earth during the lunar orbit. Because the lunar orbit forms an ellipse, with the Earth slightly offset from the center, the Moon alternates between perigee (closest approach to the Earth) and apogee (farthest distance from the Earth). During the lunar synodic month there will be two spring tides (see synodic row above). However, these spring tides commonly will be of unequal magnitude producing high spring and low spring tides, which correspond to spring tides during or near perigee (high spring) and spring tides during or near apogee (low spring). The semi-monthly inequality of the spring tides disappears when the Moon lies along the minor axis of the lunar orbit and the difference in lunar distance is minimized during subsequent spring tides. The time it takes for the Moon to move from perigee to perigee is called the anomalistic month, which is at present 27.55 days.





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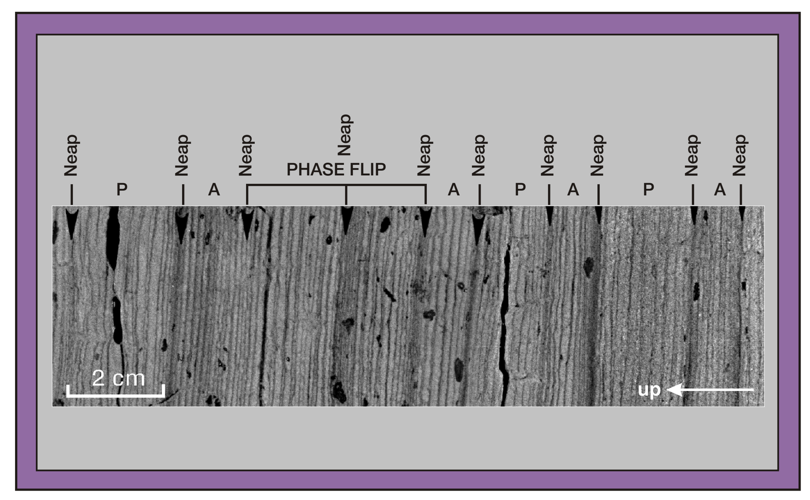

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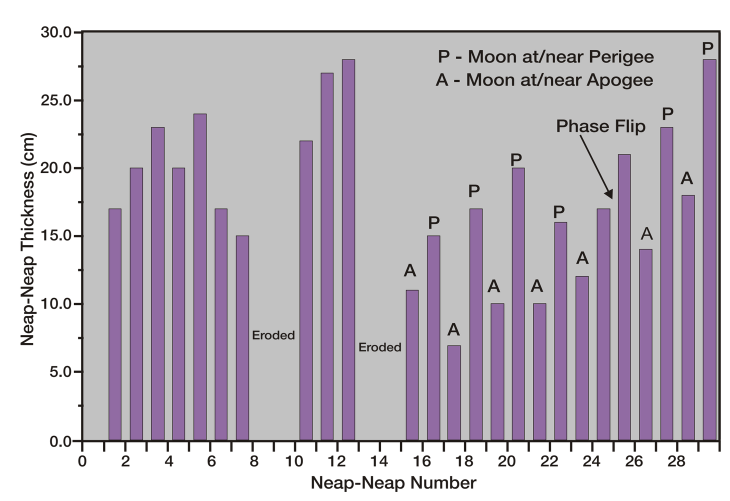
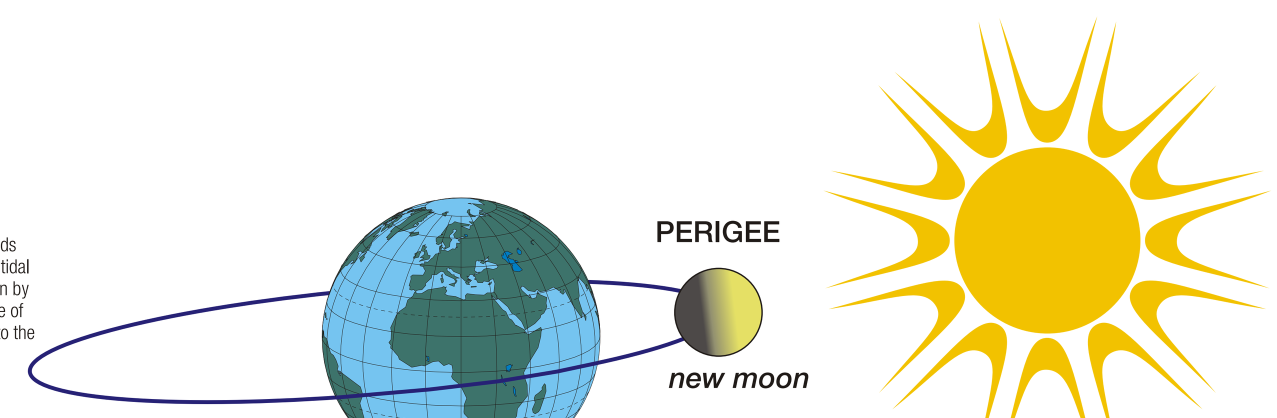
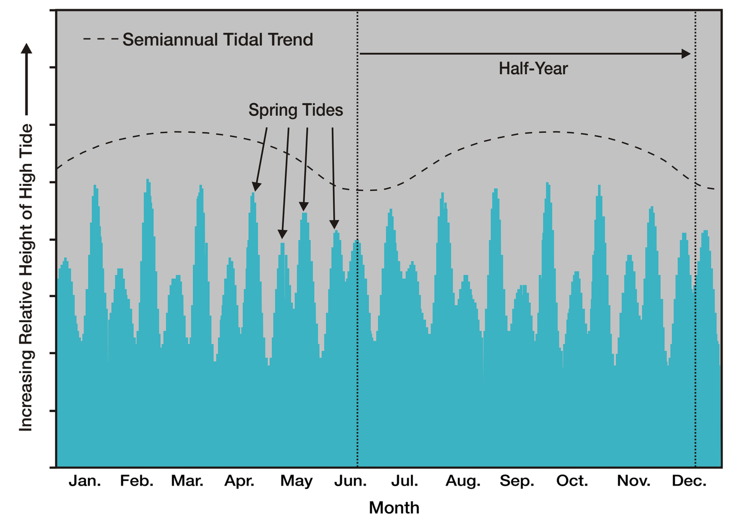


SEMIANNUAL (182.6 DAYS)

The synodic, tropical, and anomalistic periods have slightly different values. Because of this, these periods will interfere constructively twice each year causing tidal forces at these times to reach a maximum (as shown by the dashed line in the modern tides panel). The date of this tidal maximum is a function of latitude (related to the declinational effects of the Moon and Sun).





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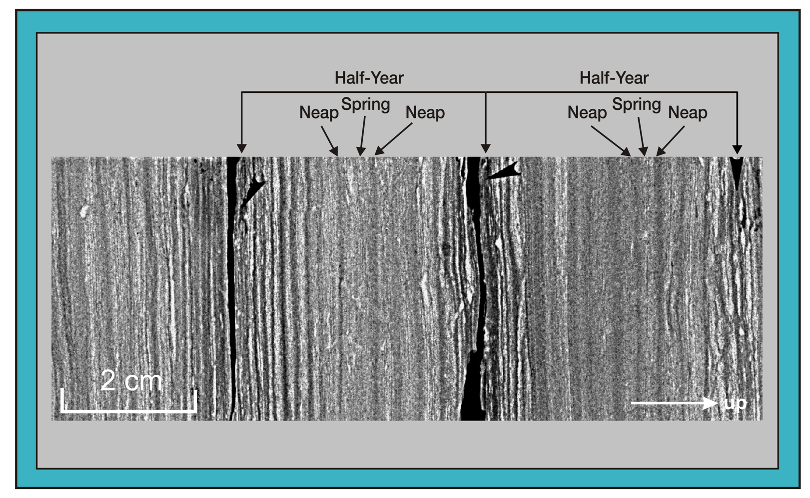

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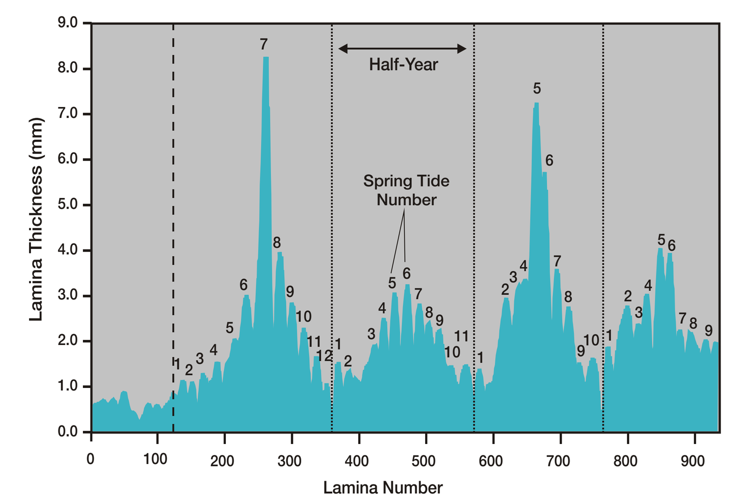

ISBN 1-56576-062-X

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1998

Cite: Kvale, E.P., Sowder, K.H., and Hill, B.T., 1998, Modern and ancient tides. Poster and explanatory notes, SEPM (Society for Sedimentary Geology). Tulsa, OK, and Indiana Geological Survey, Bloomington, IN.