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The Jurassic Period

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THE JURASSIC PERIOD

Introduction: During the Jurassic Period, Europe was covered by a shallow sea in which a rich fauna was encapsulated in sequences of limestones and shales. These Jurassic rocks were the training ground for many of the early geologists as they began to formulate some of the basic precepts of geology. Foremost amongst these was William Smith (1769-1839) who was the first to discover how to use fossils to correlate between separated outcrops. He gained his knowledge and understanding of fossils in his profession of a surveyor and in the building of canals throughout southern England where the canals were cut into these highly fossiliferous Jurassic rocks. At first, Smith simply collected fossils he found in his daily pursuits because they were interesting curios. At the time, assembling collections of fossils was a common hobby. Most of the individuals, including Smith, who made such collections had no idea of their geologic significance. That was to change one day in 1798 when he made the discovery that anywhere it was encountered, every individual rock formation contained a diagnostic suite of fossils even though the lithology may have changed slightly. It then occurred to him that the individual formations could be identified simply by collecting and identifying the fossils they contained. This idea was reinforced when he visited a friend, also an avid fossil collector, who was able to tell Smith the exact formation from which each of his fossils had been collected. It was then and there that the use of fossils for correlation and identification of rock formations and the subsequent geologic specialty of **stratigraphy** was born. For his work, Smith was not only given the unofficial title of the Father of English Geology but also the nickname of ."Strata" as in William "Strata" Smith.

The Jurassic of North America.

Eastern North America: Except for some Jurassic rocks buried deep beneath the continental shelf along the eastern margin of North America, there are no Jurassic rocks anywhere in the eastern half of the continent. By the time North America began to rift away from Europe and North Africa during the Triassic, the surface of the continent had already been worn down to quite low relief. Even so, the eastern shoreline of the newly-formed North American continent remained east of the present continental margin with the landmass extending westward as far as Utah **(Figure 1)**

The Jurassic of the Cordilleran Region: While the eastern margin of the continent was becoming a passive continental margin experiencing little tectonic activity except for the continued tensional down-faulting of the continental crust and the initiation of a geocline, a totally different scenario was occurring along the western margin of the continent. Following the Sonoran Orogeny, a eastward dipping subduction zone developed along the entire western margin of the craton in response to the westward movement of the newly-formed North American continent (**Figure 2**). A chain of arc volcanoes formed aAbove the subduction zone as andesitic magmas erupted to the surface. Simultaneously, masses of granitic magmas were intruded into the rocks below the volcanic arc, creating a dominant highland landmass comparable to the modern Japanese Islands. As the highland continued to be uplifted, a backarc (or foreland) basin formed to the east that would become a repository of sediments derived from both the volcanic arc to the west and from the landmass to the east (refer to Figure 2). To the west of the arc, rocks were continuously being stripped from the down-going oceanic plate, forming an **accretionary wedge** that consisted of a deformed mixture of oceanic basalt and oceanic sediments **(Figure 3)**. This mixture of rocks is called a **melange**, which is the French word for "mixture". As the oceanic plate continues to subduct, the accretionary wedge thickens and elevates by the addition of new materials to the *bottom* of the wedge. In time, a **forearc basin** forms between the seaward edge of the accretionary wedge and the magmatic arc. Once formed, the forearc basin becomes the site for the accumulation of marine sediments and debris from the weathering and erosion of the arc while the backarc basin accumulates sediment from the arc and from the continental land surface.

During the period of time prior to the rifting of Pangea, a vast layer of well-sorted, clean sand covered the entire western portion of the craton. One rifting began and the eastward-dipping zone of subduction and subsequent backarc basin formed along the western margin of the continent, these sands were carried by streams and deposited in the backarc basin **(Figure 4)**. The high degree of sorting and the lack of finer sediments within these sands is due to the fact that they represent multiple episodes of erosion and reworking of older sandstones located as far away as central Canada. These sands are now seen in the basal Jurassic **Navajo Sandstone**. A prominent feature of the Navajo Sandstone are spectacular cross-beds that have been interpreted as the preserved leeward portions of massive coastal sand dunes that were formed along the western margin of the land by strong onshore winds. A modern example of such an environment would be the Namibian Desert along the southwestern coastline of Africa **(Figure 5)**. During the Jurassic, the western portion of the craton was a vast desert because it was in the "rainshadow" of the volcanic highlands to the west. Today, the Navajo Sandstone can be seen in the towering cliffs of Zion National Park in southwestern Utah.

By Middle Jurassic time, the seas once again began to encroach from the north into the backarc basin along the western portion of the continent (**Figure 3**). As waters continued to move into the region, the narrow sea that occupied the backearc basin expanded eastward, eventually to become an extensive waterway known as the **Sundance Sea**. Initially, the Sundance Sea became the site of widespread carbonate, shale and evaporite deposition. The carbonates were deposited in the deeper and more open western portion of the sea while evaporites accumulated in shallow lagoons along the prograding eastern margin. These evaporite sediments are now seen in the **Gypsum Springs Formation**. By Late Jurassic, the sea had reached its maximum eastern limit and had accumulated a complex assemblage of limestones, fossiliferous shales and cross bedded sandstones referred to collectively as the **Sundance Formation**.

Late in the Jurassic, as thrusting elevated the highland to the west, streams began carrying clastic sediments from the arc highland eastward where they were spread out in the form of a vast sheet of mud, sand, and gravels. As the clastics poured into the backarc basin, the Sundance Sea was pushed back northward. What remained of the backarc basin was a non-marine foreland that became the site of stream, lake, and swamp deposition. The combined accumulation of non-marine sediments are now seen in the **Morrison Formation**, a formation famous for an amazing fossil record of the land life of the time, in particular, dinosaurs.

The Jurassic of the Gulf Coast: Beginning in Middle Jurassic time, a sea that occupied the present site of the Gulf of Mexico began to encroach onto the continental margin (**Figure 6**). Although the sediments that accumulated in this shallow sea during Jurassic time are now deeply buried beneath younger sediments, they are well know as a result of the extensive exploration for petroleum in the region. The oldest of the Jurassic formations, the **Eagle Mills Formation**, is an immense accumulation of salt, which indicates that the initial basin was landlocked and subjected to intensely arid conditions. Once buried, pressure exerted on the salt by thousands of feet of younger sediments have caused the salt to become *plastic*. Because the density of salt was lower than the enclosing sediments, domes of salt rose and penetrated the overlying formations **(Figure XX)**. As the salt penetrated the overlying sediments, the edges of the beds were warped up and truncated by the salt. Many of the porous sandstone beds through which the salt passed became reservoirs for petroleum while the overlying, impermeable shales and the salt buttress served as "cap rocks" to prevent the loss of the accumulated petroleum.

The **Smackover Formation** that overlies the Eagle Mills Formation is a fossiliferous limestone which indicates that following the initial period of high evaporation and precipitation of evaporites, an access to the open sea had opened that allowed normal marine conditions to flood into the basin. The presence of anhydrite ($CaSO_4$) in the overlying **Buchner Formation** indicate that the basin once again became landlocked, initiating another period of evaporite deposition. By Late Jurassic time, however, a widespread sea covered the entire region as far inland to what is now Arkansas. The return to normal marine conditions is recorded by the limestones of the **Cotton Valley Formation**.

Life of the Jurassic

Plant Life: The Jurassic forests consisted of cycads, cycadeoids and conifers with an intermingling of ginkgos and tree ferns with an undergrowth of ferns and scouring rushes. The cycads were so dominant in the Jurassic forests, and in the Jurassic fossil record, that the period has often been referred to as the "**Age of the Cycad**". The seed ferns that had been so dominant in the Carboniferous forests apparently failed to survive into Jurassic time. Although the widespread presence of conifers made the Jurassic forests appear quite modern, the two plants that characterize modern flora, grasses and flowering plants, were not present. However, as we will see in the next chapter, they would soon arrive onto the scene.

Insects: About 1,000 kinds of insects are known from the Jurassic, among which most of the modern orders were represented. Caddis-flies, scorpion flies, dragon flies, and beetles were common with lesser numbers of grasshoppers, cockroaches, termites, moths, and flies.

Reptiles: By the Jurassic, reptiles had taken control of all the basic earth environments from the land to the sea to the air. By the late Jurassic, both ornithischian (bird-hipped) and saurischian (lizard-hipped) dinosaurs were quite diverse; the reptiles had indeed taken over. Without doubt, the most impressive collection of dinosaur fossils is that found in the Upper Jurassic Morrison Formation. More than a dozen genera of dinosaurs have been discovered in exposures of the Morrison Formation extending from Montana to New Mexico.

It was during Jurassic time that the largest animals ever to roam the face of Earth existed. One of the more familiar of the large sauropods, **Brontosaurus**, was about 80 feet long and weighed about 30 tons (Figure 8) . But apparently, Brontosaurus wasn't the largest. Based on a few vertebrae and limb bones, the paleontologists have described another monster sauropod aptly called **Seismosaurus** that had an estimated length of 110 feet and weight of nearly 100 tons! Although these animals weighed many tens of tons, their brains probably weighed less than a pound, indicating that they were most likely inoffensive creatures. It is also interesting to note that it was once taught that these creatures were so huge that their legs could not possibly have supported them and, therefore, they must have lived in an aquatic environment where the water would help support their enormous weight. Eventually, however, abundant sauropod tracks were found intermingled with smaller dinosaurs indicates quite clearly that they were all walking on land, therefore proving that their legs were more than strong enough to support their weight.

Another familiar Jurassic dinosaur was **Stegasaurus (Figure 9)** that topped the scales at about 10 tons but had a brain that probably did not exceed a few ounces. The distinguishing feature of Stegasaurus was the row of bony plates down the spine. Originally though to be part of its defense mechanism (which it still may have been) it is now believed that they served to help regulate the body temperature of the animal much like the fins on modern lizards.

The largest and most feared carnivore of the Jurassic was **Allosaurus (Figure 10)**. As nasty as Allosaurus was, he would be superceded in the Cretaceous by the most fearsome of all dinosaurs, **Tyrannosaurus rex**. Not to leave the impression that all of the Jurassic carnivores were large, **Compsognathus** was only about 3 feet long. In fact, in general, most dinosaurs were probably not much larger than a turkey; its simply that the large ones get the most attention.

Flying Reptiles: The **pterosaur** was the first reptile to take to the air (**Figure 11**). Although referred to as a "*flying*" reptile, the animal probably should be described as a "*soaring*" reptile in that it probably could not sustain flight. This is based on the fact that because the animal had no breastbone. In modern birds, the breastbone is the point at which the strong muscles needed to flap the wings and thereby allow sustained flight are attached. Rather that being able to sustain true powered flight, the reptile soared on bat-like wings, taking advantage of the thermal air currents as do so many modern birds. Although the wing of the pterosaur was bat-like in that it consisted of skin stretched between its fingers, the pterosaur wing differs from a bat wing in that the bat uses all of its digits to support its wing while the pterosaur uses only its fourth finger (its pinky) to support the wing membrane with the other digits were located along the leading edge of the wing and used as claws. The Jurassic pterosaur had a reptilian head equipped with sharp, spike-like teeth; some had long tails to help provide stability in flight while others were tailless. Not all of the pterosaurs had the wingspans portrayed in the science-fiction movies. Wingspans ranged from that of a modern sparrow to about 4 feet. What is most important about the pterosaurs is that they obviously evolving from a four-footed predecessor. While on the ground they would walk on all fours; they attained flight by climbing a tree or precipice and launching themselves into the wind.

Maine Reptiles: By the Jurassic, **ichthyosaurs** and **plesiosaurs** had both reached their zenith **(Figure 12)**. Ichthyosaur fossils have been found in the Jurassic black shales of Germany that preserved not only the entire articulated skeleton but also the outline of the fleshy body in the form of a carbon film. The fact that some of the remains have contained unborn young indicate that they bore their young alive. Other ichthyosaur fossils have been found within which fish and cephalopods remains were preserved giving us insight as to their preferred prey.

Most plesiosaur fossils have come from Jurassic rocks. With no tail fluke, the animal propelled itself through the water using is large paddle-like fins. Along with the ichthyosaurs, the plesiosaurs were very effective marine predators.

Crocodiles resembling the modern gavial of India were abundant in both the sea and in the rivers. Marine **turtles** were also present but not with the abundance of the other marine reptiles.

The First Birds: The fossil of the first true bird, **Archaeopterix**, was found in 1861 in the lithographic Solenhofen Limestone at Solenhofen, Germany. Shortly after the fossil impression of a feather was found in the quarry, a complete skeleton of the creature to which the feather was attached was found. The toothed beak, the long tail, and the clawed forelimbs definitely speak to the reptilian ancestry of Archaeopterix. In fact, were it not for the identification of the attached feathers, the remains would definitely have been identified as a small dinosaur. Similar to the pterosaurs, Archaeopterix also lacked a breastbone, meaning that it most likely did not possess the flying ability of modern birds but rather soared on thermals like the pterosaurs. But whether it could truly fly or not, the finding of Archaeopterix records one of the most remarkable advances in the life of the Jurassic and is truly the link between dinosaurs and birds. In fact, there are those who now want birds to be included in the classification scheme as a kind of dinosaur.

Mammals: By the Jurassic, there were five orders of mammals: ***Triconodonta***, ***Symmetridonta***, ***Multituberculata***, ***Docodonta***, and ***Pantotheria***. Their presence during the Mesozoic is mostly known from teeth and jaws with only a few fragmentary skeleton parts. They were all very small and were separated into distinct orders primarily based on the cusps of the jaw teeth (**Figure 13**). The triconodonta are characterized by three simple cones in a linear series. Symmetridonta had three cones arranged in a triangle. Multituberculata had numerous cones arranged in linear rows. Docodonta had blunt, rectangular teeth, while Pantotheria had triangular jaw teeth with a broader and more complex crown. Triconodonta, Docodonta, and Symmetridonta went to extinction during the Cretaceous and left no descendents. Multituberculata survived into the Paleocene (Cenozoic Era) and also went to extinction with no descendents. It was Pantotheria that was to survive and give rise to all later mammals.

Marine Invertebrates: The marine invertebrates of the Jurassic were essentially modern. For example, corals belonging to modern families were constructing reefs. Pelecypods and gastropods resembling modern forms were very abundant. Lobstrers and shrimp-like crustaceans roamed the ocean floor. Crinoids were abundant with the large stalked forms being closely allied to the modern *Pentacrinus* that still lives in the deep water off the coast of Japan. Sea urchins were abundant and sponges were important reef-makers.

Ammonites of all sizes were represented in vast numbers of species. Belemnites up to 6 feet long were extremely common, but were at their zenith. It is almost certain that modern squids evolved from ancestors common with the belemnites.

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