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MIDDLE MESOZOIC SEDIMENTATION IN RELATION TO TECTONICS IN THE BRITISH AREA1 A. HALLAM AND B. W. SELLWOOD Department of Geology and Mineralogy, Parks Road, Oxford.

Skip to Archean Backstop, 2. Here, I sketch the big picture in Colorado, as best I can put it together, from past to present. Subsequent sections will flesh out the details, also in chronological order. The mobile belt added to the continent during this time is known as the Colorado Province. Buffalo Mountain Around 1. Colorado intrusive rocks with radiometric dates in the 1. Just Add Granite and Stir Mount Evans from Denver A large number of granitic intrusions , ductile shear zones, differential basement uplifts and rifts peppered the Colorado Province , along with the rest of the continent, in the Berthoud orogeny at 1. The Berthoud and Grenville orogenies appear to have occurred in response to convergent plate interactions playing out far to the south. The many granitic intrusions at 1. Continental Crack-up Afar Region Rifting Over the long span of Proterozoic time, several major intracontinental rifting events repeatedly tried to pull the western two-thirds of the US apart, Colorado included, just as the East African Rift splits northeast Africa today. Although an ocean-forming continental break-up never ensued in or around Colorado, the recurrent rifting left behind a rhombic network of deep-seated intersecting normal extensional basement faults. The E-W and NE-SW extensional stresses driving the rifting produced primarily north- and northwest-trending normal faults and pull-apart basins. The particularly deep west-trending Uinta rift basin was a notable exception. Many of the rift faults probably cut the entire lithosphere. During the Laramide, two surviving rift basins filled with Precambrian sediments now the Uinta and Uncompahgre formations were squeezed and inverted to form the Uinta uplift and the southern San Juan portion of the Uncompahgre uplift as well. Around 28 Ma, rifting returned to Colorado with the arrival of the Rio Grande rift. Missing Evidence Between 1. This enigmatic period is marked by a 0. Colorado spent most of the ensuing Early Paleozoic underwater, accumulating great thicknesses of tropical marine sediments primarily sandstones, limestones and shales laid down flat on the planed-off Late Precambrian basement surface. The two largest island mountain ranges developed in Coloradoâ€"Frontrangia on the east and Uncompahgria on the west. By Ma The current Rockies first rose over 70 Ma ago and are now higher than ever and still rising. The Ancestral Rockies were made of similar materials but apparently lacked the advantage of continuing uplift. If anything, the tropical and desert climates of their time would have been less erosive than the temperate climates faced by the current Rockies. The regional deformation apparently occurred in response to the onset of accelerated, low-angle flat-slab subduction of the young Farallon plate beneath the western margin of North America. The resulting basement-cored faulted uplifts and their flanking sedimentary monoclines continue to define the broad features of Rocky Mountain and Colorado Plateau topography. As always, the Laramide uplifts began to erode as soon as they began to rise. By Oligocene time, their debris had filled the structural basins surrounding the uplifts to overflowing. Today, the stream-dissected syntectonic strata of the upper Denver Basin expose a clear record of the progressive unroofing of the rising Front Range block â€" a process repeated throughout the Laramide orogen. The Laramide died out around 40 Ma Along the way, Laramide magmatism got the mineralization of the Colorado Mineral Belt off to a good start. The causes of this fiery outburst remain obscure. Over most of the state, the far-flung Tertiary volcanics have been long lost to erosion, but the San Juan Mountains and the West Elk Mountains right are major exceptions. Before their removal by erosion, volcanic accumulations helped to reposition streams directly over several then-buried Laramide uplifts. The Black Canyon of the Gunnison is but one of the results. This uplift added over 1. During the this time, the cohesive Colorado Plateau once again moved as a unit relative to the Rockies, this time to the northwest to accommodate the opening of the Rio Grand rift. Today, with the help of erosion-driven isostatic rebound , mantle-driven regional uplift continues, albeit at a much slower pace, maintaining the height of the Rockies and the Colorado Plateau in the face of ongoing erosion. Stream incision was swift and deep, and intermontane basins were

cleared of their sediments, thanks to continuing regional uplift and a wet Late Tertiary climate. Antecedent streams setting their courses on the low-relief Eocene erosional surface eventually found themselves cutting through buried uplifts that would become the ridges and even ranges of the current Colorado landscape. The range-front basins were uncovered and incised as well. Glacial Sculpting Gore Range By Pliocene time, the Rockies and the Colorado Plateau had been thoroughly dissected by stream erosion but continued to stand high between the deep canyons. The devastating glaciations that would come next, primarily in Pleistocene time, around 1. The less lofty Colorado Plateau largely escaped the ice. Maroon Bells When the last of the glaciations finally melted away at the close of the Tertiary around 10 Ka Purple mountain majesty indeed.

Chapter 2 : Tectonics and Sedimentation of Indonesia

The Mesozoic around the northern North Atlantic was characterized by a succession of extensional tectonic events separated by periods of regional subsidence governed by thermal contraction.

Towards the Late Cretaceous, large volcanic eruptions are also believed to have contributed to the Cretaceousâ€"Paleogene extinction event. Triassic[edit] The Triassic ranges roughly from million to million years ago, preceding the Jurassic Period. The period is bracketed between the Permianâ€"Triassic extinction event and the Triassicâ€"Jurassic extinction event , two of the " big five ", and it is divided into three major epochs: Early, Middle, and Late Triassic. Temnospondyls evolved during this time and would be the dominant predator for much of the Triassic. Ecosystems had recovered from the Permian extinction. Algae, sponge, corals, and crustaceans all had recovered, and new aquatic reptiles evolved, such as ichthyosaurs and nothosaurs. On land, pine forests flourished, as did groups of insects like mosquitoes and fruit flies. Reptiles began to get bigger and bigger, and the first crocodilians evolved, which sparked competition with the large amphibians that had previously ruled the freshwater world. The recent warming led to a boom of reptilian evolution on land as the first true dinosaurs evolved, as well as pterosaurs. During the Late Triassic, some advanced cynodonts gave rise to the first Mammaliaformes. The cause is debatable; [11] [12] flood basalt eruptions at the Central Atlantic magmatic province is cited as one possible cause. Rhamphorhynchus The Jurassic ranges from million years to million years ago and features 3 major epochs: In the oceans, plesiosaurs , ichthyosaurs and ammonites were abundant. On land, dinosaurs and other archosaurs staked their claim as the dominant race, with theropods such as Dilophosaurus at the top of the food chain. The first true crocodiles evolved, pushing the large amphibians to near extinction. All-in-all, archosaurs rose to rule the world. Meanwhile, the first true mammals evolved, remaining relatively small but spreading widely; the Jurassic Castorocauda , for example, had adaptations for swimming, digging and catching fish. Fruitafossor , from the late Jurassic period about million years ago, was about the size of a chipmunk, and its teeth, forelimbs and back suggest that it dug open the nests of social insects probably termites , as ants had not yet appeared. The first multituberculates like Rugosodon evolved, while volaticotherians took to the skies. The Middle Jurassic spans from to million years ago. Conifer forests made up a large portion of the forests. In the oceans, plesiosaurs were quite common, and ichthyosaurs flourished. This epoch was the peak of the reptiles. The increase in sea levels opened up the Atlantic seaway, which has grown continually larger until today. The divided landmasses gave opportunity for the diversification of new dinosaurs. Cretaceous[edit] The Cretaceous is the longest period of the Mesozoic, but has only two epochs: Early and Late Cretaceous. Some island-hopping dinosaurs, like Eustreptospondylus , evolved to cope with the coastal shallows and small islands of ancient Europe. Other dinosaurs rose up to fill the empty space that the Jurassic-Cretaceous extinction left behind, such as Carcharodontosaurus and Spinosaurus. Of the most successful was the Iguanodon , which spread to every continent. Seasons came back into effect and the poles got seasonally colder, but some dinosaurs still inhabited the polar forests year round, such as Leaellynasaura and Muttaburrasaurus. The poles were too cold for crocodiles, and became the last stronghold for large amphibians like Koolasuchus. Pterosaurs got larger as genera like Tapejara and Ornithocheirus evolved. Mammals continued to expand their range: The Late Cretaceous spans from to 66 million years ago. The Late Cretaceous featured a cooling trend that would continue in the Cenozoic era. Eventually, tropics were restricted to the equator and areas beyond the tropic lines experienced extreme seasonal changes in weather. Dinosaurs still thrived, as new taxa such as Tyrannosaurus , Ankylosaurus , Triceratops and hadrosaurs dominated the food web. In the oceans, mosasaurs ruled, filling the role of the ichthyosaurs , which, after declining, had disappeared in the Cenomanian-Turonian boundary event. Though pliosaurs had gone extinct in the same event, long-necked plesiosaurs such as Elasmosaurus continued to thrive. Flowering plants, possibly appearing as far back as the Triassic, became truly dominant for the first time. Pterosaurs in the Late Cretaceous declined

for poorly understood reasons, though this might be due to tendencies of the fossil record, as their diversity seems to be much higher than previously thought. Birds became increasingly common and diversified into a variety of enantiornithe and ornithurine forms. Though mostly small, marine hesperornithes became relatively large and flightless, adapted to life in the open sea. Metatherians and primitive eutherian also became common and even produced large and specialised genera like Didelphodon and Schowalteria. Still, the dominant mammals were multituberculates, cimolodonts in the north and gondwanatheres in the south. At the end of the Cretaceous, the Deccan traps and other volcanic eruptions were poisoning the atmosphere. The age of the dinosaurs was over. This orogeny was related to the opening of the Arctic Ocean and subduction of the North China and Siberian cratons under the Pacific Ocean. This created the passive continental margin that characterizes most of the Atlantic coastline such as along the U. Climate[edit] The Triassic was generally dry, a trend that began in the late Carboniferous , and highly seasonal, especially in the interior of Pangaea. Low sea levels may have also exacerbated temperature extremes. With its high specific heat capacity , water acts as a temperature-stabilizing heat reservoir, and land areas near large bodies of waterâ€”especially oceansâ€”experience less variation in temperature. Abundant red beds and evaporites such as halite support these conclusions, but some evidence suggests the generally dry climate of was punctuated by episodes of increased rainfall. Sea levels began to rise during the Jurassic, probably caused by an increase in seafloor spreading. Furthermore, Pangaea began to rift into smaller divisions, creating new shoreline along the Tethys Sea. Temperatures continued to increase, then began to stabilize. Humidity also increased with the proximity of water, and deserts retreated. The climate of the Cretaceous is less certain and more widely disputed. Probably, higher levels of carbon dioxide in the atmosphere are thought to have almost eliminated the north-south temperature gradient: The circulation of oxygen to the deep ocean may also have been disrupted, [22] [dubious â€” discuss] preventing the decomposition of large volumes of organic matter, which was eventually deposited as " black shale ". Not all data support these hypotheses, however. Even with the overall warmth, temperature fluctuations should have been sufficient for the presence of polar ice caps and glaciers , but there is no evidence of either. Quantitative models have also been unable to recreate the flatness of the Cretaceous temperature gradient. Flowering plants appeared late in the era but did not become widespread until the Cenozoic. The dominant land plant species of the time were gymnosperms , which are vascular, cone-bearing, non-flowering plants such as conifers that produce seeds without a coating. One particular plant genus, Ginkgo , is thought to have evolved at this time and is represented today by a single species, Ginkgo biloba. As well, the extant genus Sequoia is believed to have evolved in the Mesozoic. By the end of the Cretaceous, angiosperms dominated tree floras in many areas, although some evidence suggests that biomass was still dominated by cycads and ferns until after the Cretaceousâ€”Paleogene extinction. Some plant species had distributions that were markedly different from succeeding periods; for example, the Schizeales , a fern order, were skewed to the Northern Hemisphere in the Mesozoic, but are now better represented in the Southern Hemisphere. The extinction of nearly all animal species at the end of the Permian Period allowed for the radiation of many new lifeforms. In particular, the extinction of the large herbivorous pareiasaurs and carnivorous gorgonopsians left those ecological niches empty. Some were filled by the surviving cynodonts and dicynodonts , the latter of which subsequently became extinct. Recent research indicates that it took much longer for the reestablishment of complex ecosystems with high biodiversity, complex food webs, and specialized animals in a variety of niches, beginning in the mid-Triassic 4M to 6M years after the extinction, [32] and not complete until 30M years after the extinction. The climatic changes of the late Jurassic and Cretaceous favored further adaptive radiation. The Jurassic was the height of archosaur diversity, and the first birds and eutherian mammals also appeared. Some have argued that insects diversified in symbiosis with angiosperms, because insect anatomy , especially the mouth parts, seems particularly well-suited for flowering plants. However, all major insect mouth parts preceded angiosperms, and insect diversification actually slowed when they arrived, so their anatomy originally must have been suited for some other purpose.

Chapter 3 : Mesozoic - Wikipedia

Title: Middle Mesozoic Sedimentation in Relation to Tectonics in the British Area: Authors: Hallam, A.; Sellwood, B. W. Publication: The Journal of Geology, vol.

Sudirman 71, Jakarta Selatan; Back to main page For more than a century geoscientists had related tectonic to sedimentation by associating geosynclines with thick accumulations of sedimentation. Until the middle of 20th century, sedimentary basins were still rationalized and classified in terms of geosynclinal theory Dott, , including the publication of "Geology of Indonesia" in by R. The advent of plate tectonic theory led to a revival interest of tectonic and sedimentation since the development of this theory had provided fresh perspectives to build and constraint models of deep lithospheric behavior. Most of the sedimentary basins can now be explained in terms of plate-margin processes and consequently make the structure and stratigraphy have become more understandable. The plate tectonic theory demonstrated that one of the most important controls on sedimentation and deformation is the position of a sedimentary basin relative to either a plate or a continent-ocean boundary. Current Understanding In general, there are two major styles of sedimentary basins, 1 the basins generated by crustal extension during divergent plate movements, and 2 the basins formed by compression and crustal thickening during convergent plate movements Figure 1. On a regional scale, the general tectonic setting controls the size, shape, orientation, and structural evolution of a sedimentary basin. This can be direct effect, for example by controlling the location of source areas provenance , or can be indirect control, such as controlling the intensity of wave influence on coastal deposits since basin margin orientation determines the relationship between shorelines and prevailing wind patterns. In more detail, tectonic signatures can range from the character of parasequence sets e. Sidi, down to single beds as is the case for earthquake-derived slump deposits e. The recognition of tectonic signatures within the sedimentary succession could give important insights into the tectonic evolution of the basins at a variety of scales. The signatures can be compiled into three major groups, uplift and basin evolution, changes in subsidence rates, and folding - faulting -magmatism -diapirism Vail et al, The sediment patterns might correspondingly reflect accommodation changes generated by tectonic or eustatic factors Posamentier et al, as the accommodation available within the basin at a given time will control the geometry and character of the sedimentary fill on a gross scale. It was even argued that the stratigraphic signatures of tectonism had the most profound effect on accommodation Vail et al, Tanean et al, However, it is also recognized that there is a problem of whether sediments are responding directly to each structural developments or whether much of the basin fill postdates tectonism and contains only a remote record of preceding events Blair, A large amount of geological study has been done and the main publications that stand out are the compilation of Van Bemmelen. It is generally acknowledged that two continental shelfal regions dominate the physiographic setting of the Indonesia archipelago, the Sunda shelf area on the western part and the Sahul to the east. The tectonic styles for these two regions are completely different. In the Sundaland, the predominant factors are the frontal subduction underneath Java and oblique subduction underneath Sumatra, whereas in the Sahul region, the predominant factor is the continental collision of Australian plate with the other two Zen, Therefore the eastern part of Indonesia has more complex plate interaction, such as the Banda orogen which was formed by the collision of the Australian continental crust, mixed oceanic and continental crust of Eurasian, and the westward moving oceanic crust of the Pacific Achmad, In the main sedimentary basins of western Indonesia, the Tertiary sedimentary strata rest unconformably on a predominantly pre-Tertiary crystalline basement. The Sundaland stabilized toward the end of Mesozoic. In the back arc basins, rapid sedimentation occurred during the Tertiary, marked by syn-rift sedimentary packages at the Paleogene time, and later the sediments were then subjected to the moderate to intense folding which varied from one basin to another at the end of the Tertiary. The shelf edges appear to have been broken up by basement block faulting and the faults seem to have been continuous from the beginning of subsidence and to have controlled sedimentation e. Moss et al, ; Tsukada et

al, The growth structures led to a more deposition on the flanks of the anticlines compared to the crestal area and resulted in unique sedimentary stackig patterns Sidi, The forearc basins along this belt are tectonically heterogeneous with considerable potential for localized Paleogene and early Neogene basins Hall et al, In the Eastern Indonesia, the sedimentary basins can be considered as grossly under-explored compared to the western region. The basins can be as old as Permian and detailed information is limited mainly to the outer-arc basins of the Banda Arc. Hydrocarbon exploration was initially targeted at the Late Miocene succession and in the last decade evolved to exploring the depositionally and structurally complex Jurassic-Cretaceous syn-rift clastic sediments Henage, The tectonic history in general can be divided into two major regimes, 1 an early rifting event followed by long-lived passive margin sedimentation from the late Paleozoic to Miocene, and 2 later inversion of the basin since late Paleogene Kaufman et al, The presence of several generations of structures has implications for sedimentary patterns from time to time and hydrocarbon prospectivity. Where to From Here In conclusions, the recognition of tectonic signatures within the sedimentary successions might reveal the interaction of sedimentation, tectonic, eustatic, and possibly climatic processes in a basin. Sedimentation is related to tectonic movements in two significant ways, 1 many aspects of the origin and accumulation of sediments are controlled by large-scale tectonic movements, and 2 sedimentary strata that were horizontal when deposited but are no longer horizontal can be employed to delineate and measure the extents of structural deformations. In studying Tertiary basinal histories in Indonesia, the role of extensional tectonics in a predominantly compressional regime has become much better understood. On the other hand, new-fashioned and sophisticated techniques and equipment in the scopes of seismic reflections, wireline logging, and computerization continue to grow and change. The expanded database now allows better analysis and synthesis of the complex geological setting. Simultaneous breakthroughs in the analysis of plate-tectonic processes, depositional systems, subsidence mechanisms, chronostratigraphy, and basin-exploration methods will eventually resulted in improving actualistic models for sedimentary basins. New insights not only help reconcile relationship between presently recognized sedimentary features, global tectonics, and underlying basement, but also create new possibilities for hydrocarbon or mineral exploration. As there are no such up-to-date comprehensive publications on Indonesia, which has assemblages of tectonic-controlled sedimentary basins, a new publication is required, especially dealing with the interrelationship of plate tectonic concept and latest advances in sedimentology. AAPG Bulletin 69, Journal of Sedimentary Petrology 57, Tectonics and Sedimentation a Century Later. Earth Science Reviews 14, Plate Tectonics and Sedimentation. Tectonics and Sedimentation, pp. Society of Economic Paleontologists and Mineralogists, Tulsa. Plate Tectonics and Sandstone Compositions. AAPG Bulletin 63, Tectonic Signatures in Sedimentary Basin Fills. International Association of Sedimentologists, Glasgow. The Southern Fore-arc Zone of Sumatra: Cainozoic Basin-forming Tectonism and Hydrocarbon Potential. Proceedings Indonesian Petroleum Association, 22nd. Mesozoic and Tertiary Tectonics of Irian Jaya: Evidence for Non-rotation of Kepala Burung. Sedimentary Environments and Facies Second Edition, pp. Springer Verlag, New York. The Geological Society, London. Proceedings Indonesian Petroleum Association, 25th. Responses to Climate, Tectonism and Volcanism. Journal of African Earth Science 10,

Chapter 4 : Colorado Geology Overview

Mid-Mesozoic sedimentation can be related to a combination of eustatic rise of sea-level coupled with the elevation and subsequent collapse of rifted domal upwarps. Firstly, in the Lower Jurassic, sands were shed eastwards into southern England and Portugal from a land margining the early Atlantic rift.