SEDIMENTARY BASINS

by

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Methods of Formation

• It is common to categorise sedimentary basins according to the perceived method of formation, creating such groups as *foreland* basins (caused by lithospheric flexure), *back-arc* basins (caused by lithospheric stretching) and *pull-apart* basins (caused by strike-slip deformation of the lithosphere). Mechanisms for formation of sedimentary basins are numerous and often fundamentally linked to the concepts of plate tectonics.
Lithospheric stretching

• If the lithosphere is caused to extend, by mechanisms such as *ridge-push* or *trench-pull*, the effect is believed to be twofold. The lower, hotter part of the lithosphere will flow away from the locus of extension, whilst the upper, cooler and more brittle crust will tend to fault and fracture. The combined effect of these two mechanisms is for the earth's surface in the area of extension to subside, creating a geographical depression which is then often infilled with water and/or sediments.

• An example of a basin caused by lithospheric stretching is the North Sea - also an important location for significant hydrocarbon reserves.
Lithospheric flexure

- If a load is placed on the lithosphere, it will tend to flex in the manner of an elastic plate. The rate and degree of flexure is a function of the flexural rigidity of the lithosphere, which is itself a function of the lithospheric mineral composition and thermal regime. The nature of the load is varied. For instance, the Hawaiian Islands chain of volcanic edifices has sufficient mass to cause deflection in the lithosphere.
- The obduction of one tectonic plate onto another also causes a load and often results in the creation of foreland basins, such as the Po basin in Italy and the Spanish basins of the Pyrenees.
Strike-slip deformation

• Deformation of the lithosphere in the plane of the earth (i.e. such that faults are vertical) occurs as a result of horizontal differential stresses. The resulting zones of subsidence are known as strike-slip or pull-apart basins.
Types of Basins

• Basins are of three types; topographic, structural and sedimentary. Topographic basins are low-lying areas of the earth's surface naturally surrounded by higher areas. Topographic basins are both subaerial and subaqueous. Subaerial topographic basins range from bolsons (intermontane plains), to transcontinental alluvial valleys such as the Amazon basin. Subaqueous topographic basins range from periglacial pingo ponds to oceans. The existence of a topographic basin is necessary for the genesis of a sedimentary basin.
Evaluation of Sedimentary Basin

- As in all sedimentary basins, evolution is related, in part, to the structural history. This is particularly true for rifts whose evolving marine and continental morphologies strongly influence the composition and the geometry of the syn-rift sediments. Thus, the sedimentary sequence is a record, which is probably the best expression of rift geodynamics (Purser and Hötzl, 1988).
Types of Sedimentary Basin

- It is a matter of great importance to distinguish tectonic, or post-depositional basins from synsedimentary basins. In tectonic basins facies trends and palaeocurrents are unrelated to the basin architecture, indicating that subsidence took place after deposition of the deformed strata. In syndepositional basins, by contrast, the facies trends, palaeo- currents and depositional thinning of strata towards the basin margin all indicate contemporaneous movement.
Pre-, Syn-, and Post-Depositional Basins

• Principally, tectonic movements and sedimentary processes can interact in three different ways. These are used to distinguish between different types of sedimentary basins (Fig. 2; Selley 1985).
Post-depositional basins

- The deposition of sediments largely predates tectonic movements forming a basin structure. Hence, there is no or little relationship between the transport, distribution, and facies of these sediments and the later evolved basin structure. However, some relationship between the syn-depositional subsidence phase and the subsequent basin-forming process cannot be excluded.
Syn-depositional basins

• Sediment accumulation is affected by syn-depositional tectonic movements, e.g., differential subsidence. If the sedimentation rate is always high enough to compensate for subsidence, the direction of transport and the sedimentary facies remain unchanged, but the thickness of the sediment in certain time slices varies.
Syn-depositional basins

- If the sediment thickness increases toward the center of the basin, the basin structure is syn-depositional, but there was hardly a syn-depositional morphological basin controlling the sedimentary facies of the basin. If sedimentation is too slow to fill up the subsiding area, a morphological basin will develop. Then, the distribution and facies of the succeeding sediments will be affected by the morphology of the deepening basin.
Pre-depositional basins

- Rapid tectonic movements predate significant sediment accumulation and create a morphological basin, which is filled later by post-tectonic sediments. The water depth in the basin decreases with time, although some syn-depositional subsidence due to sediment loading is likely. Sediment transport as well as vertical and lateral facies developments are substantially influenced by the basin morphology.
Fig. 2. A. Post-depositional basin created by tectonic movements after the deposition of sheet-like fluvial and lake sediments; younger syn-tectonic basin fill is removed by subsequent erosion. B. Syn-depositional tectonic movements control varying thicknesses of fluvial and shallow-marine sediments and generate a basin-fill structure, although a morphological basin barely existed. C. Rapid, pre-depositional tectonics creates a deep morphological basin which is later filled up by post-tectonic sediments. The geometry of the former basin can be derived from transport directions and facies distribution (after Einsele, 1992).
Transitions between basins

- Of course, there are transitions between these simplified basin types and certain basins may show a complex history and therefore contain pre-tectonic as well as syn-tectonic or post-tectonic sediments.
Basins, Embayments and Troughs

- Sedimentary basins generally cover tens of thousands of square kilometres, but their sizes are not diagnostic. Distinction is made, however, between basins \(\textit{sensu stricto}\), embayments and troughs (Fig. 132). Basins \(\textit{sensu stricto}\) are saucer shaped and subcircular in plan. Embayments are areas which are not completely closed structurally, but which open out into a deeper area. Troughs are linear basins.
Diagram to illustrate the nomenclature of basins. Lines indicate structure contours, arrows indicate depositional palaeoslope, A: a basin sensu stricto, subcircular in plan and structurally closed, B: an embayment, opening out at one side to a structurally lower area. C: a trough, structurally closed and elongated.
Basins, Embayments and Troughs

- These three basin types are essentially unmetamoiphosed and undeformed by tectonism. These features distinguish them from the linear metamorphosed tectonized sedimentary troughs which are termed "geosynclines".
Basins, Embayments and Troughs

- The thinning of the sedimentary cover towards the basin margin may be erosional or non-depositional, shown by intraformational thinning. These margin types differentiate post-depositional from syndepositional tectonism. The axis of a basin is a line connecting the lowest structural points of the basin, as in a synclinal axis. Similarly the axes of troughs may plunge. The depocentre is the part of the basin with the thickest sedimentary fill.
Depocentre, basin axis, and topographic axis

• It is very important to note that the depocentre and basin axis need not be coincident, neither need they coincide with the topographic axis of the basin (Fig. 133). This is particularly true of asymmetric basins with large amounts of terrigenous sedimentation on the limb of maximum uplift. In gentle basins, with pelagic fine-grained and turbidite fill, depocentre, axis and topographic nadir may coincide.
Cross-section to illustrate that topographic and structural axis need neither be coincident with each other, nor with the site of maximum sedimentation (the depocentre). Isopach maps are not necessarily, therefore, reliable indicators of palaeotopography.
Axial elements of sedimentary basins

- **Basin axis** is the lowest point on the basement surface
- **Topographic axis** is the lowest point on the depositional surface
- **Depocentre** is the point of thickest sediment accumulation
Depocentre movement

- It is a common feature of many basins that the depocentre moves across the basin in time (Fig. 134). This may reflect a migration of the topographic axis of the basin, or merely a lateral progradation of the main locus of deposition across an essentially stable basin floor.
Cross-section of two sedimentary basins showing the lateral migration of depocentres with time. Upper the Gbon basin of W. Africa, an ocean margin basin. (Data from Belmnte et al., 1965). Lower: the Maranhao basin, of Brazil, an intracratonic basin (Data from Mesner and Wooldridge, 1964).
Arches, palaeohighs, schwelle, axes of uplift or positive areas

• Basins are separated one from another by raised linear areas where the sediment cover is thin or absent. These are variously termed arches, palaeohighs, schwelle, axes of uplift or positive areas. Similarly, major basins are commonly divisible into sub-basins, troughs and embayments by smaller positive features. Figure 135 illustrates the distribution of different basin types on the South American Continent.
Attempts to classify the various types of sedimentary basins

- Attempts to classify the various types of sedimentary basins have been made by many geologists, notably Weeks (1952), Halbouty et al. (1970) and Perrodon (1971). These classifications vary according to the defining parameters which have been chosen, and according to the purpose for which a scheme was drawn up. As with most geological phenomena, basins can be broadly grouped into several fairly well-established families, whose limits are ill-defined.
Basin Morphology and Depositional Environments

- The geometry of an ultimate basin fill is controlled mainly by basin-forming tectonic processes, but the morphology of a basin defined by the sediment surface is the product of the interplay between tectonic movements and sedimentation. It is true that a sedimentary basin in a particular tectonic setting often undergoes a specific developmental or subsidence history, but its morphology, including water depth, may be controlled largely by other factors, such as varying influx and distribution of sediment from terrigenous sources.