An Overview of Tectonic and Sedimentation Inter-relationship

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Introduction

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, 1978), including the publication of "Geology of Indonesia" in 1949 by R.W. van Bemmelen. 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). From these two major groups, several detail classifications of sedimentary basins in terms of plate boundary settings have been attempted, such as Dickinson (1974), Mitchell & Reading (1986) and Miall (1990).

On a regional scale, the general tec-

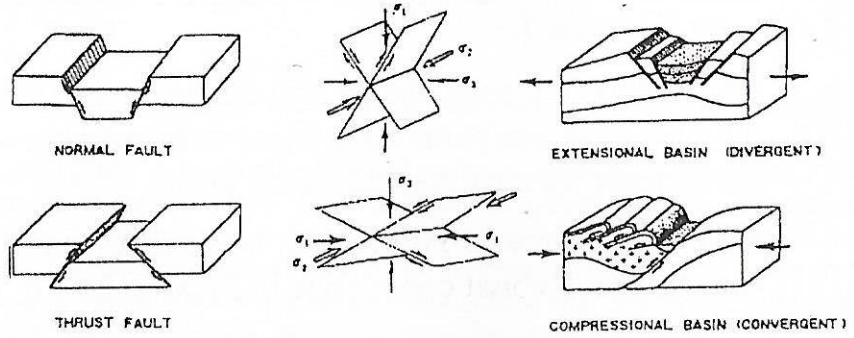


Figure 1: Two major tectonic movements which resulted in two different styles of sedimentary basins.

tonic 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.g. Sidi, 1998) down to single beds as is the case for earthquake-derived slump deposits (e.g. Tiercelin, 1990).

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, 1991). The recognition of these imprints can help to define both basin type and paleogeography by identifying the location and character of active faults (Frostick & Steel, 1993). The sediment patterns might correspondingly reflect accommodation changes generated by tectonic or eustatic factors (Posamentier et al, 1988) 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, 1991). In a more specific study,

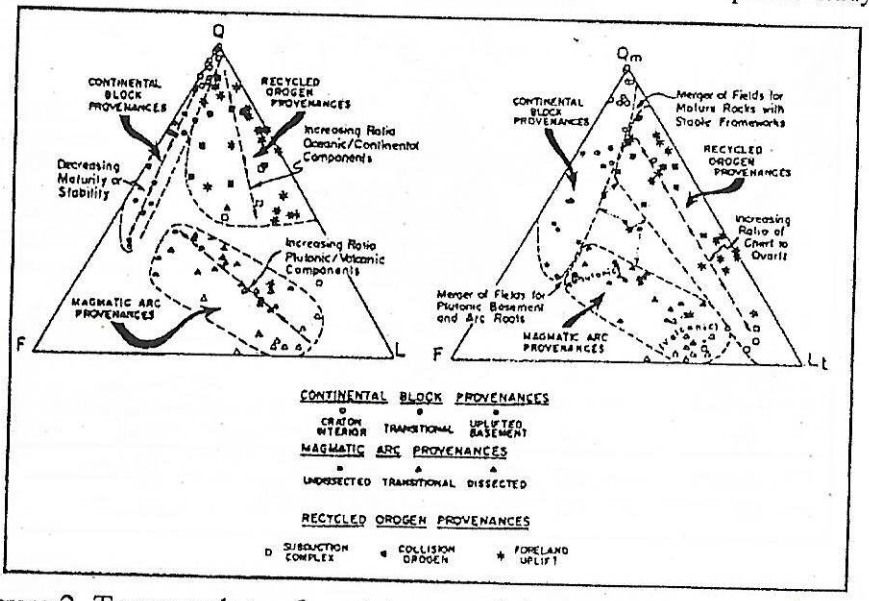


Figure 2. Ternary plots of sandstone modal composition related to different type of provenances and tectonic origins (Dickinson & Suczek, 1979).

the detrital framework modes of sandstone suites from differet kind of basins can be associated with the provenance types produced (Figure 2) by plate interactions (Dickinson & Suczek, 1979) and reveal the tectonostratigraphic evolution of the basin (e.g. Tanean et al, 1996). 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, 1987).

Indonesia's Regional Framework

Indonesia lies at the junction of three major crustal plates, the Pacific, the Australian, and the Eurasian (Figure 3). The intersection of these plates is responsible for the creation of one of the world's most complex geological settings. A large amount of geological study has been done and the main publications that stand out are the compilation of Van Bemmelen. So far, however, there are still no such comprehensive publication replaces Van Bemmelen's which utilizing modern concepts and broader amount of data.

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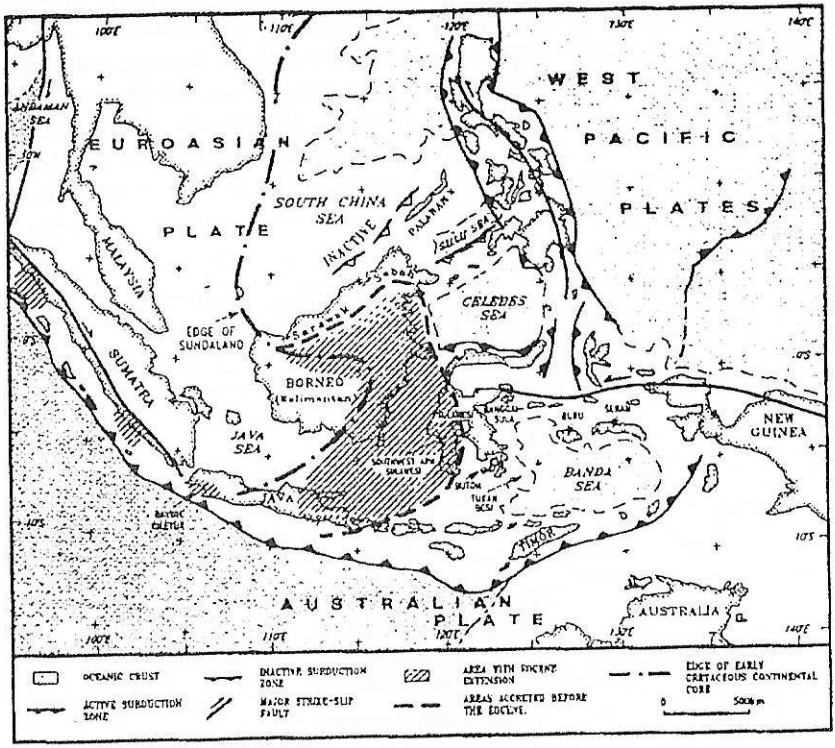


Figure 3. The tectonic setting n Indonesia in relation with surrounding major plates (van de Weerd & Armin, 1992)

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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, 1994). 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, 1998).

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.g. Moss et al, 1997; Tsukada et al, 1996). Section balancing study also indicated that the structural development produced inversion structures and controlled sedimentation patterns (Ferguson & McClay, 1997). The growth structures led to a more deposition on the flanks of the anticlines compared to the crestal area and resulted in unique sedimentary stacking patterns (Sidi, 1998).

The forearc basins, such as the Sunda arc of Sumatra, include typical constructed forearc characters of Paleogene to recent age with major unconformities attributed to eustatic sea level changes and local tectonism (Beaudry & Moore, 1985). The forearc basins along this belt are tectonically heterogeneous with considerable potential for localized Paleogene and early Neogene basins (Hall et al, 1993).

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, 1993). 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, 1997). 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 equipments 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.

Conclusion

In general the sedimentation process are related to the tectonic movements in two significant ways:

1. Many aspects of the origin and accumulation of sediments and strata are controlled by large scale tectonic movements.
1. Sedimentary strata that were horizontal when deposited but are no longer horizontal can be employed to delineate and measure the extents of structural deformation.

The Indonesian region is known for its tectonic records which are also control of the sedimentary basins. 'The Geology of Indonesia" has put these two geological aspects integrally and become a remarkable comprehensive book of the region. As the tectonic concept has been changed from 'geosynbcline' to 'plate tectonic' and more data available since then, an update of the book is required.

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New Publications

RELATIVE ROLE OF EUSTASY, CLIMATE, AND TECTONISM IN CONTINENTAL ROCKS; edited by K. W. Shanley, & P. J. McCabe, 1998, SEPM Special Publication #59

PALEOGEOGRAPHIC EVOLUTION AND NON-GLACIAL EUSTASY, NORTHERN SOUTH AMERICA, edited by J. L. Pindell & C. Drake, 1998, SEPM Special Publication #58

Cover Story

The Ciletuh Formation volcanic sandstones at Daheu Island, West Java is interpreted as submarine fan gravity flow deposits. The sandstone to mudstone ratio of this section is 10:1 to 15:1 with greater lateral continuity bedding and less frequent scouring. This section is composed of mainly thickly bedded (0.6-4.0 m), medium to very coarse grained sandstone (Facies B) with interstratified units of very fine to medium grained sandstone (Facies D). The D facies beds are capped with well-developed, clay-rich tuffaceous mudstone or marl (i.e. Bouma Te division).

Source:
Schiller, D. M., Garrard, R.A., Prasetyo, L., 1991, Eocene Submarine Fan Sedimentation in Southwest Java, 20th IPA Annual Convention Proceeding