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# Dynamic Features of Angular Unconformity Formation —Extensional and Compressional Angular Unconformities

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**Abstract** Angular unconformity is one of the most direct and strongest evidences for approving the tectonic movements of the earth's crust. Its dynamic genesis process has been understood to be mainly related to the compressional setting for a long time. Especially, in a detailed structural analysis for a specific region, when an angular unconformity is discovered people would regard it as the result of orogenic movements of a certain period or a certain episode and neglect the extensional facts. Based on a dialectical point of view of extension-compression, this paper has proved that angular unconformities can be formed not only in compressional settings, but also in extensional ones. Further more, their geological features are compared and he possible genetic mechanisms for angular unconformity under different dynamic settings are studied.

**Key words**: angular unconformity, dynamic genesis, extensional angular unconformity, compressional angular unconformity

## 1 Introduction

Angular unconformity is one of the most fundamental concepts in geological studies. For a long time, it has been taken as one of the most direct and strongest evidences for approving the tectonic movements of the earth's crust (Zhu and Song, 1990). However, in the past, people used to emphasize too much the compressional actions, but neglect the existence of the extensional ones when trying to understand the movements of the earth's crust. Therefore, they lopsidedly understood the formation mechanisms and dynamic genesis mechanisms of angular unconformities, e. g., taking all the angular unconformities as the results of compressions. Especially, when an angular unconformity was discovered in detailed structural analysis in a specific region, people often related it to orogenic movements of a certain period or a certain phase and neglected the extensional facts. Its dynamic formation was understood also as a single genesis, e.g., it was thought that angular unconformity was formed because of the compression of the earth's crust resulting in the horizontal strata's folding, doming, denudation and subsidence for new sediments. For quite a long period of time, this genesis mode has been widely accepted and applied. However, in resent years, some new theories and new concepts have been put forward, which has deepened people's understanding of some geological phenomena. Especially, in the last 10 to 20 years, the concept of extensional structures has enabled the geologists to understand geological phenomena from a deeper point of view—the contradictory unity of compression and extension (Ma, 1982).

In resent years, we have systematically studied the tectonic features and evolution mechanisms of he Junggar basin and Sichuan basin, and found great differences in geological features existing between the angular unconformities inside the sedimentary cover of a basin and those in an orogenic belt. These two kinds of angular unconformities were formed in different dynamic settings. To illustrate this, we had introduced two concepts, the "extensional angular unconformity" and the "compressional angular unconformity" (Li et al., 1998).

## 2 Comparisons of Geological Features of the Extensional and Compressional Angular Unconformities

In respect of tectonic dynamics, angular unconformities can be classified into two categories: the extensional angular unconformity and the compressional angular unconformity. In geological features, they have at least the following differences:

(1) On tectonic dynamic setting: Extensional angular unconformities mainly exist in an extensional dynamic setting of the earth's crust. They are the products of synsedimentary tectonic movements in basins. Meanwhile, compressional angular unconformities mainly occur in a

compressional dynamic setting. They are the products of the compressional orogenic period.

(2) On geological setting: Extensional angular unconformities mainly appear in the sedimentary cover of sedimentary basins, as very much constrained local angular unconformities between two sedimentary covers. In plane, they are shaped in isolated circles or minor axes. In the Sichuan basin, both the Caledonian Leshan-Longnuisi paleouplift and the Indosinian Luzhou-Kaijiang paleohigh are good examples. Contrarily, the compressional angular unconformities generally appear between the (folded) basement and the sedimentary cover in a basin or an orogenic belt.

(3) On deformation intensity: Compared with the compressional angular unconformities, the extensional angular unconformities have much weaker deformation intensity; especially in the underlying formations of the unconformity surface, the angles between the underlying formations and the unconformity surface range from several degrees to more than 10 degrees. The folds of the underlying formations are relatively wide and gentle. Faults are seldom developed. When away from the surface, the discomformity or conformity appears quickly; e.g., the scope of an extensional angular unconformity is quite limited. On the contrary, for a compressional angular unconformity, the angles between the underlying formations and the unconformity surface are generally several tens of degrees. The folds of the underlying formations are relatively tight, occurring in rows and belts with obvious directions. Relatively more faults are developed in the underlying formations.

(4) On development of unconformity surfaces: Compared with the compressional angular unconformities, the extensional ones have narrower unconformity surfaces, representing shorter time intervals. For example, in the Tuositai area on the southern edge of the Junggar basin in Xinjiang, the Xishanyao Group ($J_2x$) and Toutunhe Group ($J_2t$) are two continuous formations. An extensional angular unconformity occurred just in the very short time interval between them (Li et al., 1998).

(5) On the lithology and lithofacies of the two sets of formations above and below the unconformity surface: Generally, the lithologic characters and lithofacies of the two sets of formations above and below the extensional angular unconformity surface have only small differences, while those of the compressional one may differ very greatly from each other. This is mainly because that the extensional angular unconformity was formed in a setting where the earth's crust was under tensile stress to form basins and continuously received sediments. However, the formation of the compressional angular unconformity experienced first the compressional orogenic setting of the earth's crust, and then the extensional setting to form basins and receive sediments of the overlying formations of the unconformity surface. For example, on the southern edge of the Junggar basin, there is a compressional angular unconformity between the Paleozoic folded basement and the Cenozoic sedimentary cover. Great differences are seen between the overlying and underlying formations of the surface. The underlying is a set of epimetamorphic rocks dominantly of marine facies, while the overlying a set of fluviolacustrine sedimentary rocks.

## 3 Probes into the Formation Mechanisms of the Extensional and Compressional Angular Unconformities

The earth's crust has two basic movement modes: extension and compression, which are in contradictory unity. If we observe the earth as a large system, then in a certain geological period (time fixed), when a certain area was under compressional orogeny, its neighboring area must be in an extension to form basins (Deng and Ren, 1996; Ma et al., 1996). Meanwhile, if a specific area was under extension to form a basin and receive sediments of tremendous thickness in a certain period of time, it might be transformed into compressional orogeny to form an intensive orogenic belt and be denuded in another period of time. The compressional angular unconformity was formed in this dynamic setting of continuous transformation between compression and extension. It has recorded the tectonic changes of the earth's crust. We are all very familiar with the mode how an angular unconformity was formed in the compressional setting. Its process can be briefed as hereafter described: The original nearly horizontal formation was folded and uplifted by regional compressive stress in a compressive dynamic setting. Then, it was leveled off by denudation. Finally, it entered gradually into the extension and basin-forming setting to receive sediments, thereby forming a regional compressional angular unconformity. This mode has been taken as a classic one for many years. It is perfectly correct for explaining the regional compressional angular unconformities in orogenic belts or the compressional angular unconformities between the folded basement and the sedimentary cover in basins. From observations of its formation process, it is found that it has experienced two completely different dynamic settings: the early compression and folding and the late extension and re-deposition. Hence, the two sets of formations separated by the unconformity surface may be very different in lithology, lithofacies, magma intrusions, faulting, etc. Many examples of this kind of angular unconformities can be listed, such as that between the Pre-Sinian folded basement

and the sedimentary cover in the Sichuan basin (Fig. 2).

The mode of how an angular unconformity is formed in an extensional setting can be recognized as hereafter described. Because of extension, the earth's crust was thinned and subsided to form basins and receive sediments of tremendous thickness. This process was dominated by the formation of extensional normal faults. In profile, the combination of a series of extensional normal faults is expressed as the tectonic combination of graben-horst of the basement (Fig. 1A). In plane, it is expressed as local huge domes and huge depressions. It is reasonable to imagine that as the extension went on, the overall basin was in subsidence and taking sediments (Kusznir and Ziegler, 1992). However, because of the differences in dips of the normal faults, or in friction coefficients in the faulted zone, or in pore fluid pressures, etc., the movement velocities of the faults were not the same (Jamison, 1987). The overall subsidence of the basin was in fact a differential uplift-subsidence. Therefore, in a certain period of time, certain areas (such as the horst-developing areas) were in a relatively uplifting condition and were hence denuded, forming extensional angular unconformities of limited ranges in the basin (Fig. 1B). Then, in another period of time, some other areas were in a relatively uplifting

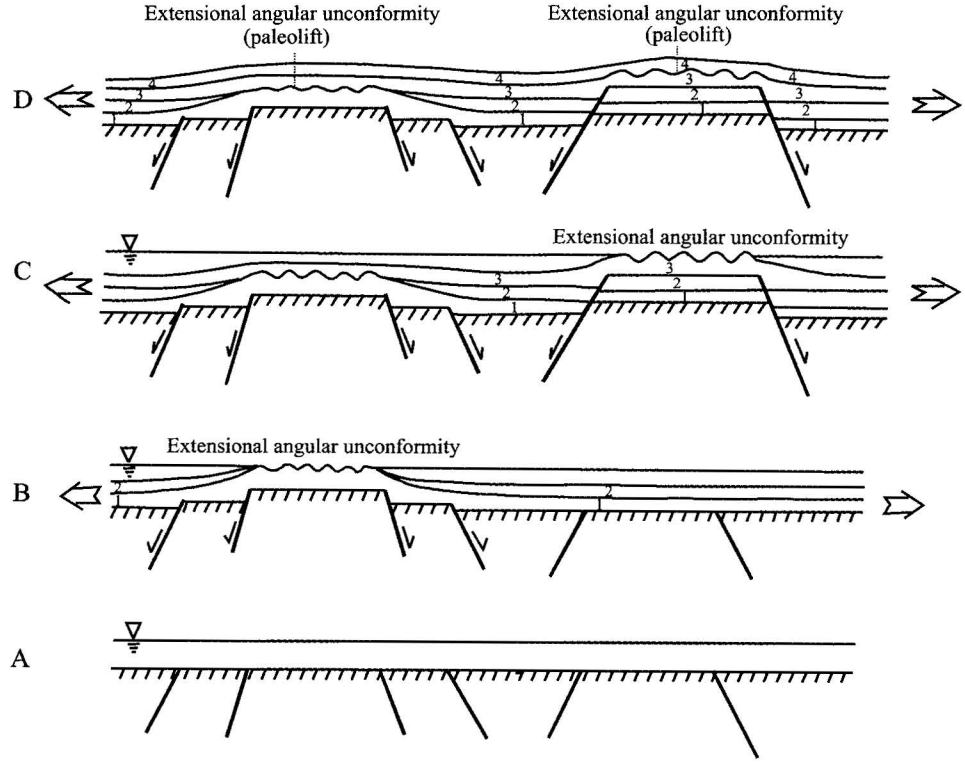


Fig. 1. The model for forming extensional angular unconformities under an extensional setting.

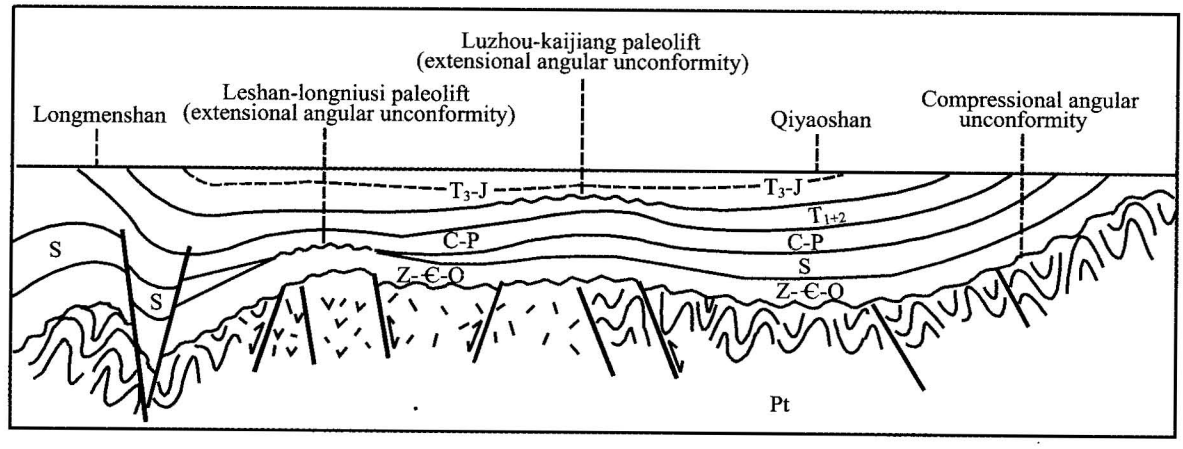


Fig. 2. Schematic geological profile before the Cretaceous sedimentation.

condition and were hence denuded, resulting in extensional angular unconformities of limited ranges in the basin (Fig. 1C). That gave rise to the extensional angular unconformities (paleohighs) presently discovered through drilling in the basin (Fig. 1D).

## 4 A Case Study

Figure 2 is a geological profile of the Sichuan basin before the Cretaceous sedimentation. It is compiled based on the geological features of the basin and combined with data from others.

In this figure, it is a regional compressional angular unconformity between the Pre-Sinian (Pt) folded basement and the sedimentary cover. In the underlying formations (Pt) of the unconformity surface, folds are very tight. Faulting and magmatism are also very well developed. This is quite different from the overlying formations. Above this formation, in the sedimentary cover, the Leshan-Longniusi paleohigh and Luzhou-Kaijiang paleohigh are local extensional angular unconformities. Below and above the unconformity surface, the formations have similar lithologic characters, similar lithofacies, similar folds, similar faults, similar magmatic movements, etc. This means that the tectonic dynamic setting in which an extensional unconformity was formed was much more stable than that when a compressional one was formed.

## 5 Conclusion

Based on analyses of the dynamic genesis of angular unconformities, it is understood that there are a lot of differences in the formation mechanisms and geological features between the extensional and the compressional angular unconformities. This is of great significance both theoretically and practically. It has deepened people's understanding of the tectonic movements of the earth's crust and has provided a new approach for comprehensive basin tectonic analyses. It has broken the limitation that people understood the unconformities in basins only from the compressional point of view. Therefore, it has a profound practical significance for studies on hydrocarbon migration, accumulation and entrapment inside a basin.

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