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Types and Briyfly Origins of the Extensional Fault-Related Folds

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Abstract: - Not until Hamblin（1965）described rollover folds associate with nomal faults did topographers realize that extensional fault-related folds, which is of great significance to exploration of hydrocarbon, exist wildly. The theory of extensional fault-related folds developed rapidly in rencent several decades, having established relatively systematic achievement. This paper briefly documents the type and origin of folds associate with extensional fault by summarizes foreign and domestic literatures. It is suggested that the classification of extensional folds incorporates both axial trend and mechanism of folds. Extensional folds are divided into three principal types including longitudinal, transverse and oblique folds on the basis of the geometry relationship between the axial fold and the associated normal fault. Futher more, these three types of folds are divided into several detailed categories according to their origin mechanism respectively.

Key words: *- normal fault, extensional fault-related fault, origin mechanism*

I. INTRODUCTION

The fault-related folds have been broadly attention by geologists since Rich(1994) came up with the viewpoint that folds above the hallingwall of reverse fault were closely related to the geometry of the faults. Whereas, Peole considered most folds were resulted from contraction, transpression and diapirism mechanism incipiently until Hamblin (1965) described rollover folds associate with nomal faults did topographers realize that extensional fault-related folds exist wildly as well[1]. Extensional folds occur in most Extensional basins and regions such as the Suez rift, the Red Sea, Rhein Graben and so on. The classification of the extensional fault-related folds vary through geologists. Nevertheless, most scholars agree with the classification scheme that Schlische proposed in 1995 which divided Extensional folds into three categories, namely longitudinal and transverse folds based on the relationship between the axial trend of fold and the strike of associated normal fault[2]. Further more, other geologists(eg. Janecke et. al.)insist that oblique folds should be distinguish from the two kinds of folds stated above.

Longitudinal folds are folds whose axial trend lie parallel or subparallel to the strike of associated normal fault, angle between the axial and the strike restrict within 22.5°. Oppositely, axial trend of transverse folds are perpendicular to the strike of normal fault, angle between the axial and the strike range from 67.5º~90º. The term oblique folds describe fold with a trend that is between 22.5º and 67.5º from the strike of the associated normal fault[3]. Additional, Compound folds are formed by more than one mechanism(See Detail classification in table 1 and figure 1).

Table 1. Styes of folds in extensional settings

Longitudinal folds		Transverse folds		Oblique folds
Fault-bend folds	Rollover folds associate with listic fault	Displacementgradient folds	Folds associate with isolated fault	Fault-bend folds
	Bend folds associate with ramp-flat-ramp fault		Folds associate with segmented fault	
Fault propagation folds		Fault-line deflection folds		Transtensiona l folds
Normal drag folds		Transverse constrictional folds		Accommodation zones folds
Reverse drag fold		Accommodation zones folds		-
Isostatic folds		-		-

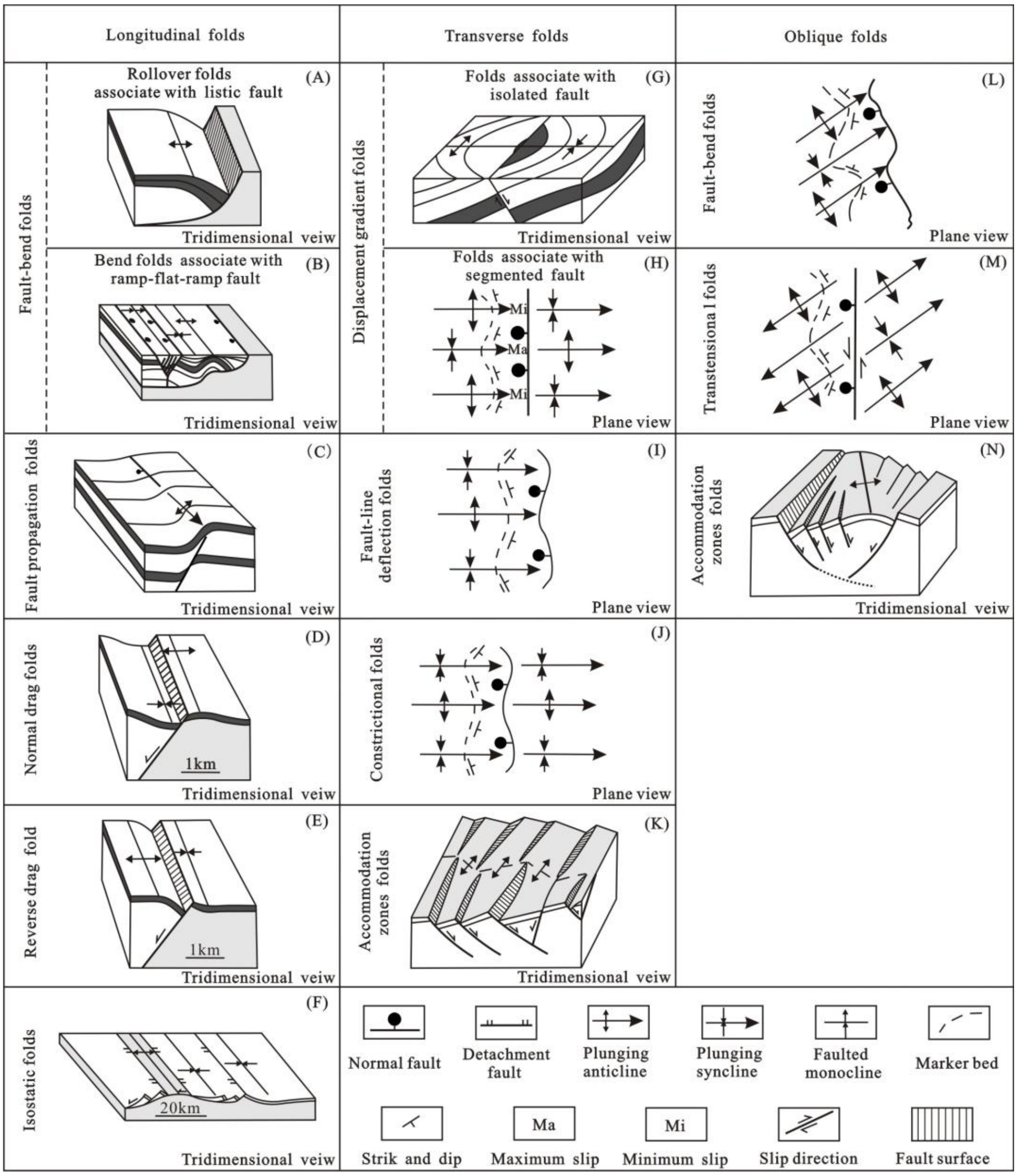

Fig.1 Diagram illustrating the common types of extensiona l folds

II. LONGITUDINAL FOLDS

2.1 Fault-bend folds

Fault-bend folds result from beds above hangingwall sliping along the fault surface, mechanism of which can be interpreted by gravity-driven. The geometry of Fault-bend fold is controlled by the shape of the fault surface. Further more, Longitudinal fault-bend folds could be divided into rollover folds associate with listic fault and Bend folds associate with ramp-flat-ramp fault according to the shape of the associate fault surface(fig.1 A and B). This kind of folding only occurs in hangingwall.

2.2 Fault propagation folds

Fault propagation folds are termed forced folds as well. They form at the tip of steep normal fault as a result of its upward propagating[4]. Ductile strata incorporate the displacement of the underlying fault produce an assymetric monocline with close， steep forelimb and open， gently backlimb(Fig.1C).

2.3 Normal drag folds

Normal drag folds derives from frictional resistance along the normal fault plane where hanging wall beds are dragged up the fault surface and footwall beds are dragged down the fault surface， which result in a shape that a syncline develops in hangingwall, whereas a anticline develops in footwall(Fig.1D).

The geometry of normal drag folds are compared closely to the fault propagation folds, nevertheless the origin of them are disparate. Normal drag folds form after beds being faulted by normal fault as a result of frictional drag along the fault plane(Fig.2A), while the propagation folds developed before the layer being faulted by fault result from upward propagation of the underlying normal fault(Fig.2B).

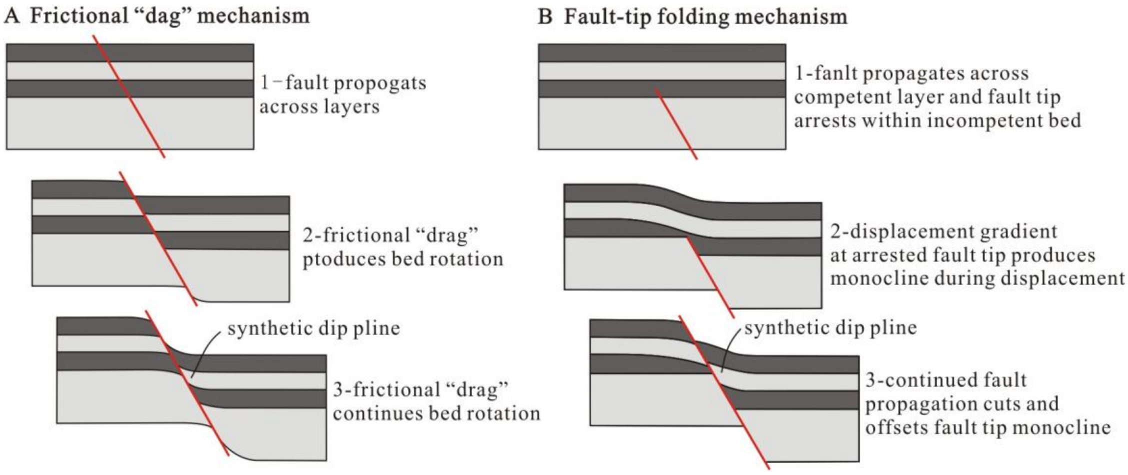

Fig.2 Different mechanism of normal drag folds and fault propagation folds(from Ferrill et. al.，2012)

2.4 Reverse drag fold

In contrast to normal drag folds, reverse drag folds form hanging-wall anticlines and footwall synclines which are produced by elastic and flexural response of beds to faulting(Fig.1E). The geometry of its hangingwall folds are similar to the rollover folds, however ,their genesises are different as document above.

2.5 Isostatic folds

Isostatic folds are folds that have a relatively large scale and wide spacing, forming in response to differential unloading of the footwalls of normal faults Fig.1F).

III. TRANSVERS FOLDS

3.1 Displacement gradient folds

As we know, displacement is commonly greatest at or near the center of the fault and decreases to zero at the fault tips. Thus, displacement gradient folds are formed as a result of the different displacement distribution along fault strike and are divided into folds associate with isolated fault and folds associate with segmented fault based on the growth mechanism of the associate fault.

3.2 Fault-line deflection folds

Fault-line deflection folds are folds related to nonplanar fault surfaces. Typically Synclines form at recesses of the fault surface, whereas anticlines form at salient.

3.3 Transverse constrictional folds

The direction that perpendicular to the regional extention direction is the minimum extention axis(namely the maximum constrictional strain axis), along which orientation could produce slightly constricting in tridimensional strain field. Thereby, transverse constrictional folding would occur when come across ductility layers that are liable to be deformed. The transverse constructional anticlines and synclines are aligned and concordant(Fig.1J).

3.4 Accommodation zones folds

Accommodation zones folds develop when the normal faults that develop along accommodation zones tent to be segmented ,with changing in dip orientation[5](Fig.1K).

IV. OBLIQUE FOLDS

4.1 Fault-bend folds

Oblique fault-bend folds are produced by folding attribute to sliping of layers along non-planar fault planes,with corrugations on fault planes oblique to the strike of the normal fault, and rigid stock of footwall. Notably, probably no folds will occur in footwall.

4.2 Transtensiona l folds

They occur in two sides of normal faults when orientation of regional extention is oblique to the strike of the normal faults, and folding occurs not only in the hangingwall but also in the footwall of faults, with axial of folds parallel to principal extentional direction,while obique to the strike odf the associate fault.

4.3 Accommodation zones folds

Oblique accommodation zones folds develop at the accommodation zones between opposite dip normal faults or fault system when the fault tips emplace along srike and partially overlap.

V. CONCLUSIONS

The principal types of extensional folds include longitudinal, transverse and oblique folds. In addition, detailed classification based on mechanism of folds origin such as extensional fault bend folds, extensional fault propagation folds, fault drag folds, reverse drag folds, isostatic folds, displacement gradient folds, fault-line deflection folds, transverse constrictional folds, accommodation zones folds, transtensional folds are distinguished.

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