Effects of basement uplift on passive-margin salt basins: new insights from the Kwanza Basin, Angola

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Abstract

Basement beneath the Kwanza Basin, Angola, has been reactivated several times since the end of Neocomian rifting and continental separation. Basement uplift has played a major role in controlling the timing and magnitude of seaward translation detached above Aptian salt.

The first major basement deformation was a hitherto unrecognized period of crustal uplift beneath the continental rise that began around 75 Ma (Campanian). Uplift of an overlying thick salt plateau in deep water led to line-sourced salt extrusion and seaward advance of the Angola Salt Nappe over the abyssal plain. Exposure of the nappe toe removed the buttress provided by abyssal-plain cover, which triggered gravity-driven seaward translation of Kwanza Basin sediments.

A second period of basement uplift in the Miocene was more complex. A group of uplifts below the shelf steepened the bathymetric slope and greatly accelerated downslope translation. Other uplifts located farther inboard had negligible effect on regional bathymetric slope. Instead, only a few small fold-and-thrust belts formed in sediments next to and above the basement blocks. Finally, Miocene–Recent uplift and erosional unroofing of the African continental interior supplied abundant new sediment to the passive margin. Most of this sediment flux bypasses the Kwanza Basin and is accumulating on the abyssal plain. Aggradation of sediments on the abyssal plain has reduced the overall relief of the system and blocked salt-nappe advance. Detached deformation and translation are thus currently slowing to near zero in distal regions.

Introduction

The overall effects of basement uplift on passive margins are seemingly well understood. Uplifts in the proximal part of a basin enhance gravity-driven deformation in two ways: by increasing the overall slope and by increasing erosional unroofing, which supplies a source area for sediments to prograde into deep water. Uplifts in the distal part of a basin, on the other hand, decrease the slope and so retard gravitational deformation.

South Atlantic salt basins provide an ideal setting for testing this accepted principle. Basement uplifts have been reported on both sides of the Atlantic Ocean, and Aptian salt provides an ideal detachment surface for gravity-driven deformation. For example, Cobbold et al. (2001) presented evidence of Cretaceous–Tertiary basement uplift in landward parts of the Campos, Santos, and southern Espírito Santo Basins. As would be expected, the coastal uplifts tilted the Brazilian margin and enhanced thin-skinned deformation above salt.

Our paper describes more complex results of basement uplift on the conjugate African margin. Hudec and Jackson (2002) presented evidence of several phases of postrift uplift in the Kwanza Basin, Angola. Here we describe the effects of this uplift on salt-detached deformation.

Basement uplift and detached deformation in the Kwanza Basin

The Kwanza Basin formed during Neocomian rifting and breakup of Gondwana. After rifting, thick Aptian evaporites accumulated in the Inner and Outer Kwanza salt basins, separated by a chain of basement highs on which salt was thin or absent (Figure 1; Hudec and Jackson, 2002). Differential thermal subsidence during the Albian tilted the basin seaward and initiated seaward translation of the postsalt section. Extensional growth faults and contractional growth folds in lower Albian strata show that seaward translation began very soon after salt deposition but waned in the late Albian, probably because of thinning of salt lubricant beneath the extensional province.

Next, uplift of the seaward part of the Kwanza Basin began in the Campanian (~75 Ma) and may have continued episodically into the Tertiary. Total uplift was ~1 km. The predicted result of deep-water uplift would be a decrease in basin slope and retardation of detached deformation. However, these things did not happen. Instead, Campanian uplift triggered a renewal of salt-detached deformation, which had been inactive since the late Albian (Figure 2).

How could uplift at the seaward end of a basin have this counterintuitive result? We propose that a combination of two factors contributed to the outcome. First, the uplift is known to have affected the outer salt basin but not the adjacent abyssal plain. The elevation difference from the landward end of the basin to the abyssal plain was thus unchanged; distal uplift changed only the shape of the bathymetric profile connecting the two fixed ends of the basin. Second, the uplift formed an escarpment at the seaward end of the salt basin; uplift of the scarp removed the stabilizing buttress provided by abyssal-plain sediments, which led to the breakout and extrusion of the Angola Salt Nappe. Late Cretaceous distal uplift therefore decreased the resistance to translation while leaving the gravitational driving force unchanged.

Following the renewal of detached translation in the Campanian, deformation continued at a modest pace until the middle Miocene. Then the rate of seaward translation increased at least tenfold (Figure 2). Lunde et al. (1992) and Lundin (1992) recognized that renewed Tertiary translation was caused by uplift of the landward rim of the basin. Lunde et al. (1992) suggested that this uplift created a massive 1–2 km-high plateau in the present onshore Kwanza Basin, but this hypothesis is contradicted by widespread Oligocene–lower Pliocene marine deposits there (Jackson et al., 2003).

Instead, patterns of stratigraphic thinning and erosion suggest that Miocene crustal adjustments of the margin formed several smaller uplifts (Figure 1). The largest of these was the Congo Craton that rose as part of the African Superswell (Nyblade and Robinson, 1994) to form the mountains to the east of the basin. Within the Kwanza Basin, several smaller blocks were reactivated to create local basement highs.

These uplifts had varying effects on detached deformation, depending on location within the basin. Reactivation of the Flamingo, Ametista, and Benguela Platforms, which underlie the present continental shelf (Figure 1), tilted the Outer Kwanza Basin seaward and triggered the surge in translation observed in Figure 2. Structures associated with this accelerated deformation are restricted to the Outer Kwanza Basin.

In the Inner Kwanza Basin, by contrast, Tertiary uplift of the Congo Craton and reactivation of the Cacuaco, Cabo Ledo, and Morro Liso Uplifts were not associated with any significant seaward translation. Each of the uplifts involved lateral compression, so that small thrust belts and squeezed diapir provinces formed adjacent to the basement highs (Hudec and Jackson, 2002).

Uplift of the Congo Craton also created a major sediment source area, with the potential to drive seaward translation via progradation of the Kwanza shelf edge. However, most of the sediment sourced from the uplifted continental interior was deposited in major deltas to the north and south of the Kwanza. This sediment bypassed the basin but was transported onto the Kwanza abyssal plain via deep-water contour currents, increasing the abyssal-plain sedimentation rate from 8 m/m.y. to >130 m/m.y. in the late Miocene. Aggradation on the abyssal plain buttressed the toe of the Angola Salt Nappe and lowered the overall slope of the system, decreasing the driving force for seaward translation. As a result, detached deformation began to slow in the late Miocene and has now virtually stopped (Figure 2).

Conclusions

Detached deformation is governed by a complex interplay of driving and resisting forces. Variations in those forces control when and where deformation occurs. Basement uplift can perturb the balance of forces in several ways, the simplest of which is by changing the degree of basinward tilt. However, the Kwanza Basin shows that more complex effects are also possible. For example, in the Kwanza Basin, distal uplift triggered detached deformation (by enabling breakthrough of the Angola Salt Nappe) and a proximal uplift that inhibited deformation (by sedimentary bypass and aggradation of the abyssal plain). The Kwanza Basin shows that basement tilt is certainly an important driving force, but that variations in resisting force can in some cases be even more important and lead to paradoxical or counterintuitive relationships.

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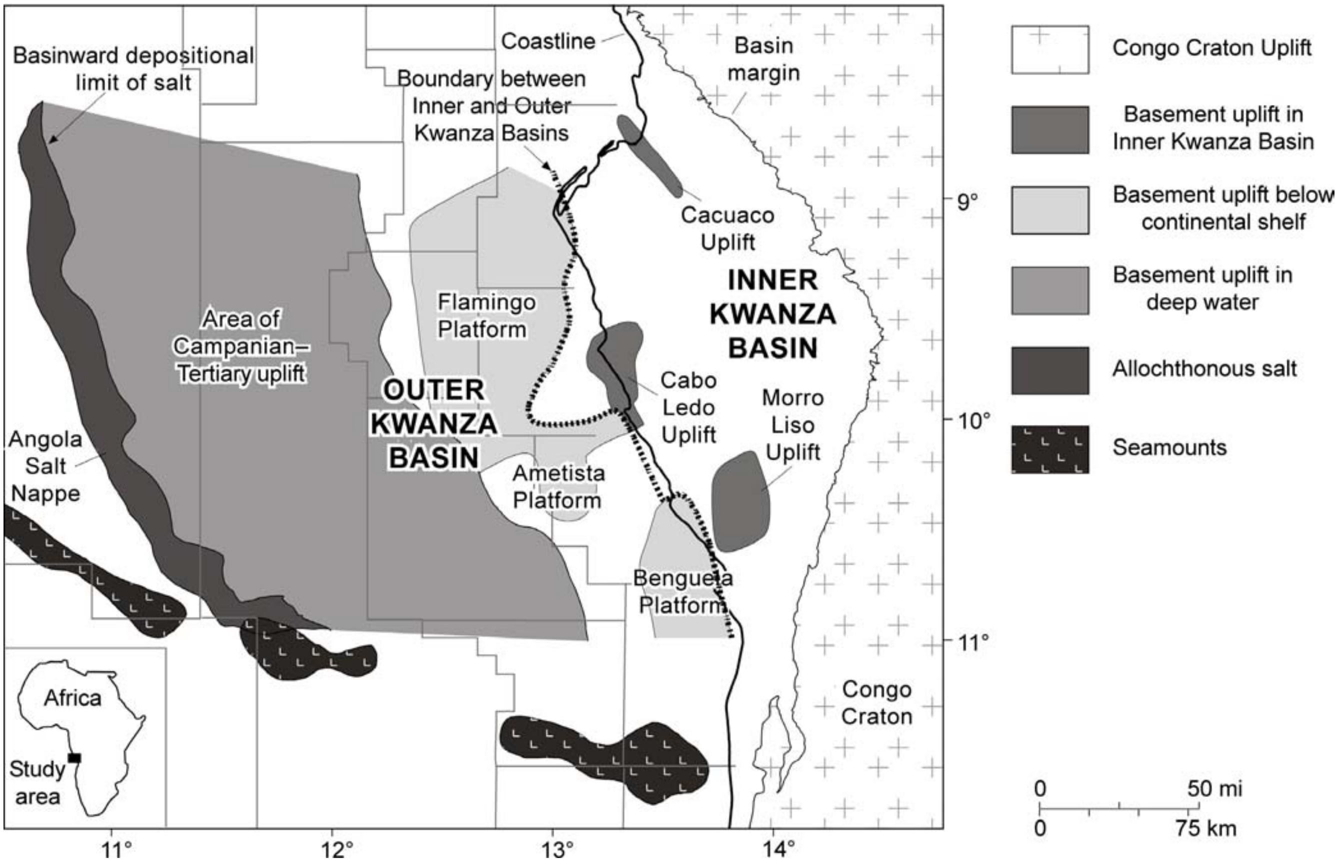

Figure 1 – Map of basement uplifts in the Kwanza Basin, Angola.

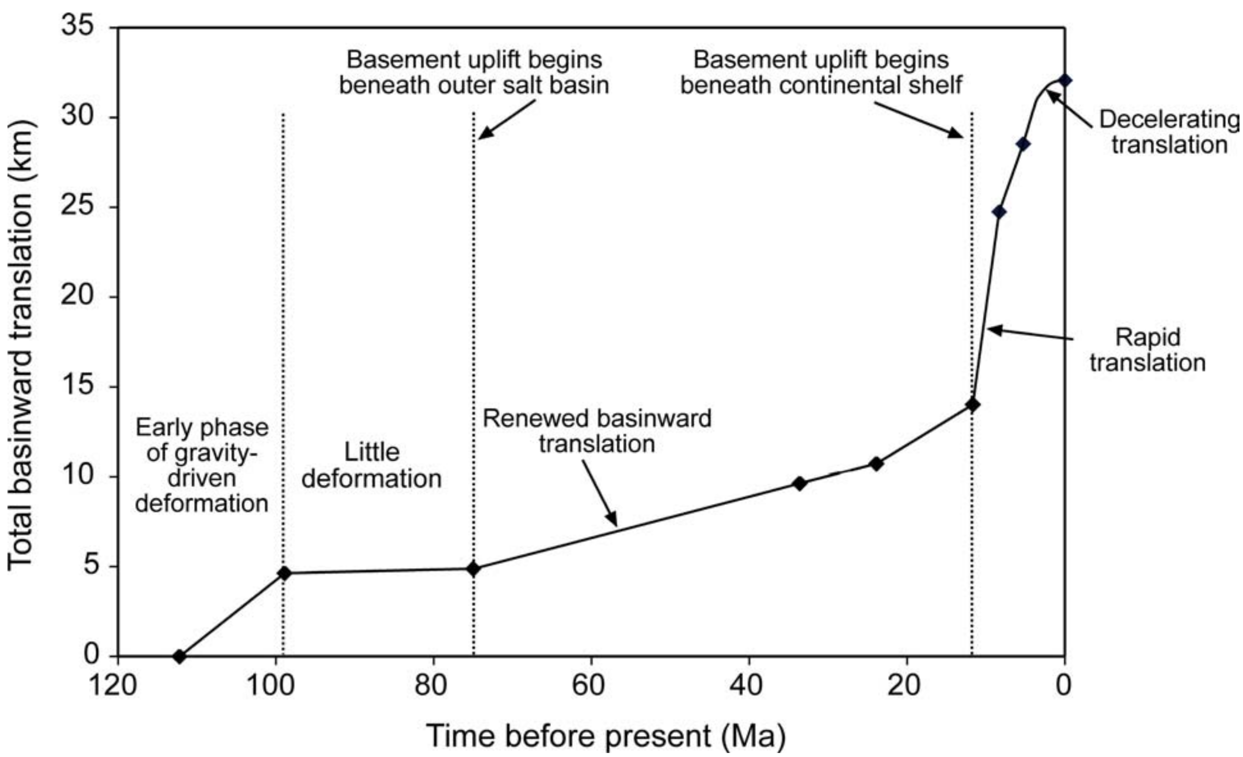

Figure 2 – Basinward translation through time in the northern Kwanza Basin, derived from cross-section restoration.