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3D kinematics of gravity driven deformation in large deltas and control by the delta front migration : the case of the Plio-Pleistocene of the Eastern Niger Delta

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The occurrence in large shelf edge deltas of gravity driven deformation related to overpressured shales is now well documented in many natural examples. In this context, differential loading by deltaic sedimentation has long been identified as a major driving mechanism and the migration seaward of the slope (progradation of the sedimentary profile) is often coeval of the migration of the deformation system (extensional/compressional system). Numerical modeling has recently shown that, for a prograding differential load, the extensional domain is remains localized below the slope break of the delta front and is not distributed across the deltaic plain or the platform like in a static case. This has however not been documented on natural examples yet.
The aim of this paper is therefore to document and discuss the implications of the delta front migration, in time and space, on the kinematics gravity of driven deformation, in a case where stratigraphic framework is detailed enough to discuss deformation kinematics and sedimentary supply at high temporal resolution (x0.1 Myr). Using the example of the eastern Niger delta we determined the evolution in 3D of the gravity driven deformation at the scale of the whole system, i.e. from the deltaic plain to the most distal deposits on the abyssal plain, i.e. including both the extensional and compressional domain. We established the deformation pattern at high temporal resolution (a few tenth of Myr) although for a short time interval (the last 4 Myr).
Deformation was partitioned into 3 domains. The upslope extensional domain was characterized by a major EW trending graben, over a 200 km long and 30 km wide, with depocentres reaching locally 4 km in thickness. The transitional domain displayed an eastern domain where the tapering out sedimentary wedge is thinner and the deformation is restricted to a few folds and a western domain with a thicker sedimentary wedge and a more important deformation accommodated by thrust related folds. The compressional front of the gravity driven deformation system was characterized by a fold and thrust belt. We showed that the extensional deformation evolved significantly through time: (i) it decreased in amount and rate (sediment accumulation rate ranging from 1500 m/Myr to less than 300 m/Myr in the main depocentres), (ii) it evolved from distributed over the whole area to localized (either to the west or to the East) and (iii) was accommodated by asymmetric grabens with either synthetic or antithetic main faults. In the compressional domain, the spatial variability of deformation through time was more limited but followed the same evolution (spatial migration and intensity variation) demonstrating the strong coupling between the extensional and compressional domains: the larger the extension, the larger the compression, and this, both in time and in space
We showed that this deformation pattern was closely linked the spatial and temporal migration of the delta front. At the scale of the whole of the Plio-Pleistocene, the rate of deformation of gravity driven deformation system was directly related to the sedimentary supply reaching the Easter Niger Delta and both decreased over that period. At the scale of studied time increments, spatial variations of sedimentary supply induced spatial variations in deformation intensity and rate. Also, the pressure gradient associated with the migrating slope break of the delta front also localized the extensional domain as the area of delta front migration and the extensional area were always superimposed.