

Development of a Pennsylvanian Fan Delta Within a Carbonate Shelf Sea

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The Pennsylvanian Gamonedo Formation in northern Spain contains an unusual association of facies: limestones and conglomerates. The limestones include grainstone, packstone, and mudstone, and fossil abundance and diversity are everywhere high. Crinoids, fusulinids and other foraminifera, brachiopods, rugose corals, ramose bryozoans, gastropods, ostracodes, scaphopods, phylloid algae, and oncolites are plentiful. Deposition occurred as aggrading shoals of lime sand on a nearshore shelf. Water depth fluctuated from below wave base where mud accumulated with the fossil grains (argillaceous skeletal packstone) to above wave base where fossil grains mixed with quartz sand and limestone extraclasts (sandy skeletal grainstone). Lime mudstone formed in a tidal-flat environment wherever deposition raised the sediment surface to sea level. In addition, dozens of thick interbeds of limestone conglomerate occur in the Gamonedo Formation. Clasts consist mostly of limestone rock fragments plus smaller quantities of sandstone rock fragments, quartz and chert grains, and large bioclasts. The source area comprised older Pennsylvanian limestone formations in a newly raised tectonic highland along the basin margin. Conglomerate beds are frequently graded (normal, inverse-to-normal, or inverse), and the texture may be matrix- or clast-supported. They formed as sediment-gravity flows on a marginal-marine fan delta when hyperpycnal flows transported the gravel through channels incised into the carbonate shelf. Vertical changes in grain size reflect on the timing and nature of tectonic activity. The cumulative thickness of limestone conglomerates is greatest in eastern outcrops, which suggests that most of the coarse sediment was carried along the eastern margin of the fan delta. From east to west, however, these sediment-gravity flows exhibit a subtle facies change—from debris flow to turbidity current to grain flow—hinting that the fan-delta's surface became flatter in that direction. The cumulative thickness of fossiliferous limestones is greatest in western outcrops. The western fan delta was less frequently disturbed by sediment-gravity flows, and after the passing of each flow, the carbonate environment reestablished itself. Where not overwhelmed by tectonically driven sediment, the western limestones exhibit a meter-scale cyclicity attributed to small-scale fluctuations of relative sea level.