Olistostromes and the Onset of Subduction

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Abstract

Olistostromes found in a number of major fold belts are of an age comparable with the start of underthrusting as indicated by attendant arc-related volcanism. They occur at the inner edge of inferred accretionary wedges, and are commonly associated with contemporaneous basaltic rocks. These olistostromes may result from disruption of the crust during lithosphere fracturing at the commencement of subduction. Components of the olistostromes provide evidence concerning the site of initial underthrusting.

Olistostromes or sedimentary melanges, disorganised clastic accumulations, characterised by the presence of allocthonous masses of great size, are indicative of strong tectonic activity at the time of their deposition. The best known are those of the Italian Appenides, and the Wildflysch of the Western Alps, that formed mainly late in the sedimentary history of the Alpine geosyncline and signal the start of major orogeny. However, some olistostromes date from an earlier phase in fold belt development, and I believe that these constitute a distinctive group, members of which provide information concerning the time and setting of the onset of subduction.

Characteristics of this group of olistostromes are: deposition significantly before climactic orogeny, an absence of compelling evidence for low-angle overthrusting at the time of their formation, and the presence of contemporaneous basaltic volcanic rocks. Olistostromes contain a variety of blocks indicative of more than a single source, they are generally thick and of regional extent but may have been deposited in a relatively short time interval, and they are frequently associated with serpentinite masses and other altered mafic and ultramafic igneous rocks.

Olistostromes which I regard as members of this group occur in the Dunnage Formation of Newfoundland (Horne, 1969; Kay, 1976), the Gwna Beds of northwest Wales (Greenly, 1919; Shackleton, 1969; Wood, 1974), near Ballantrae in southwest Scotland (Peach and Horne, 1899; Church and Gayer, 1973) and in Wisemans Arm district of northeast New South Wales (unpublished data of E.C. Leitch and P.A. Cawood). All are found close to inferred ancient consuming plate boundaries, and available evidence suggests that they are contemporaneous with the commencement of subduction. Thus the age of the Dunnage Formation (Middle Cambrian-Early Ordovician) probably overlaps that of the arc-related volcanic rocks of the Summerford Group (Kay, 1976), the Arenig Ballantrae olistostromes are of about the same age as that suggested for the start of subduction in southern Scotland (Dewey, 1971), the Gwna Beds have not been closely dated but are possibly a little older than the Arvonian lavas, to the southeast, that may have formed a Late Precambrian arc (Wood, 1974), and the Wisemans Arm olistostromes are probably Early Devonian, and hence of an age similar to that of the first activity on the magmatic arc to their west (Leitch, 1975).

Development of the olistostromes at the start of subduction is also suggested by their palaeogeographic position. The Dunnage, Ballantrae and Wisemans Arm rocks border the most arcward exposures of the impacted component of accretionary wedges, and are succeeded, away from their associated magmatic arcs, by upthrust oceanic and/or trench deposits (Kay, 1975; McKerrow, Leggett and Eales, 1977; Leitch, 1974). Rocks arcward of the olistostromes probably accumulated in fore-arc basins. The Ballantrae sequence is unconformably overlain by later Ordovician rocks of this type (Williams, 1962) whereas the Dunnage and Wisemans Arm sequences are in fault contact with fore-arc material. Large-scale folding has obscured the palaeogeographic relationships of the Gwna Beds and neighbouring units.

Kay (1976) considered that the Dunnage Formation may have accumulated in a subduction-related trench and the Gwna Beds, and the Woolomin Beds (with which the Wisemans Arm rocks are associated) have also been in part so interpreted (Wood, 1974; Leitch, 1974). The presence of clasts of shallow water rocks (e.g. oolitic and coralline limestone and highly vesicular pillow basalt), and those of inferred deep water origin (e.g. radiolarian chert), as well as boulders possibly derived from oceanic crust and upper mantle (mafic and ultramafic igneous rocks), accords with an active trench environment, where accumulation of gravity-displaced sedimentary rocks of both oceanic and littoral derivation is feasible and outcrops of mafic and ultramafic rocks have been discovered (Bowin, Nalwalk and Hersey, 1966; Fisher and Engel, 1969).

But olistostromes are probably not normal trench deposits. The presence of a fossiliferous limestone bed in the Dunnage formation, and of interstratified vesicular basaltic rocks in the Dunnage and at Ballantrae do not suggest abyssal depths, and, indeed, volcanic activity has not been recognised in modern trenches, in spite of the frequent presence of basalt flows in the olistostrome-dominated sequences.

I suggest that these olistostromes result from the widespread disruption of crustal rocks accompanying the inception of underthrusting of oceanic lithosphere. At this time, a fracture must propagate to the base of the lithosphere (except where a consuming plate boundary forms at the site of an earlier transform fault), and this fracturing, and the start of underthrusting result in the extensive faulting of surficial rocks in the vicinity of the developing trench. The irregular morphology of fault scarps, tilted blocks, and fault angle depressions provides ideal conditions for the gravitational displacement of large volumes of rocks which accumulate as a mixture of large slide blocks and material carried downslope in debris flows, slumps and turbidity currents. Basic volcanism, triggered by pressure release and movement of water into the mantle, is a likely accompaniment of initial underthrusting, building up a broad welt on the edge of the over-riding plate and producing pillow lavas that are intercalated in the developing olistostrome sequence. These early volcanic rocks may themselves become incorporated as slide blocks, or may build up emergent islands that contribute epiclastic debris into the evolving trench. Hydration of upper mantle material leads to the emplacement of serpentinite diapirs along major fractures and this material and entrained exotic blocks might occasionally penetrate to the ocean floor to become mixed with the surficial components of the developing olistostrome.

As well as dating the commencement of underthrusting, these *olistostromes* provide important information on the setting in which subduction commenced. Thus the abundance of chert blocks, sometimes associated with manganiferous lenses, in the Wisemans Arm sequence suggests underthrusting began in an oceanic realm. At Ballantrae abundant blocks of bedded chert, basic volcanic rock and gabbro and ultramafic rock suggest a similar setting but with greater disruption of the crust and upper mantle at the inception of subduction. The Gwna olistostromes contain abundant blocks of limestone, greywacke and quartzite suggesting disruption close to a continental margin; these rocks overlie a thick sequence of quartzite and greywacke beds which supports suggestions of the proximity of a continental source. A strong continental influence is also recognisable in the olistostromes of the Dunnage Formation which contain slide masses and boulders of greywacke, quartzose sandstone, calcilutite and conglomerate, the latter including fragments of granodiorite and dacite.

Although all of the olistostromes discussed above have undergone low grade metamorphism, only parts of the Gwna Beds contain phases indicative of high pressure facies series. The precise grade of the Dunnage is apparently unknown but the rocks lack signs of high pressure low temperature alteration, and the rocks at Ballantrae and Wisemans Arm are of prehnite-pumpellyite metagreywacke facies. The frequent absence of high pressure metamorphic minerals may be a further reflection of the development of the rocks at an early stage during underthrusting. As initial members of accretionary wedges they would have occupied high levels, and later impacted wedge material underthrusting beneath them would be more likely to show the effects of deep tectonic burial.

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