The Active Margin Carbon Cycle

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Active Margins and Riverine Systems

Tectonic processes on active margins are intrinsically coupled to the transport of sediment and associated organic matter. Over geologic time scales (>1 Ma), uplift and mass wasting of sedimentary rock from uplifted accretionary wedges inject recycled organic C (e.g. kerogen), along with modern material into the marine environment (Fig. 1). The magnitude and nature of the organic carbon (OC) delivered to the marine realm can also be affected on short time scales due to event based disturbances (e.g. earthquakes, landslides). Hence, tectonic processes in active margins are intrinsically coupled with the transport of sediment and the associated organic matter. River systems located adjacent to active margins are responsible for some of the largest sediment yields on the globe (Milliman and Syvitski 1992). Importantly, those located on active margins discharge a larger percent of sediment directly to deep ocean basins (Milliman and Syvitski 1992).

Current Knowledge of OC on Active Margins

In an active margin system, the recycled pool represents a significant portion of the OC buried in the marine environment (Blair et al., 2004) (Fig. 2). Small mountainous rivers along active margins export particulate organic carbon that is 7-75% fossil C (kerogen) in content, with the remainder derived from modern vegetation and millennial aged soil sources (Leithold et al., 2006; Drenzek et al., 2009; Blair et al., 2010). Recycled C is more inert than younger forms derived from plants and soils, and this inherent recalcitrance should lead to persistence, transit to the deep marine environment, and incorporation into the subduction zone.

Subduction zones are the ultimate sink for sediment and associated OC. To determine global C budgets and volatile production in subduction zones it is necessary to understand the recalcitrance of OC entering these regions. In active margins a significant fraction of OC reaching subduction may be the result of rapid terrestrial erosion by small mountainous rivers. OC from this source which reaches the offshore subduction environment is likely to be recycled C. The relative fates of these organics depend on reactivity and environment.

Unanswered Questions

The fate of recycled C beyond the mid-slope is unknown. Most studies go no further than to describe OC in terms of marine and terrestrial sources and do not consider the presence of fossil material even though the sediments themselves are derived from organic-bearing lithologies. However, the fate of recycled C has significant implications for the global O_2 cycle because the oxidation of fossil C, along with pyrite, is considered to be an important control of pO_2 (Berner and Canfield, 1989). The only known locations for oxidation of recycled C are in subaerial sedimentary rock exposures (Petsch et al., 2000), and soils within large river watersheds on passive margins (Bouchez et al., 2010; Blair and Aller, 2011). To the extent that OC inventories of subduction margins remain approximately constant through time by recycling and reburying fossil C, pO_2 levels would be buffered against rapid changes. The resistance of recycled C to de-volatilization will influence the nature of C incorporated into deep burial and ultimately C budgets for subduction zones.

We know little about the multicycle-C mixture as it moves from the nearshore to the subduction zone. Is the recycled fossil C delivered to the frontal edge of the accretionary wedge to be cycled again and/or subducted? Or is it oxidized and ultimately replaced by marine C during transport offshore? What are the fates of the younger terrestrial and marine OC components? The answers to these questions have significant implications for C-cycle models and the interpretation of the organic geochemical record. The state of our knowledge concerning the nature of sedimentary particulate organic carbon on subduction margins is too primitive to allow us to fully appreciate the importance of these systems to global C and O cycles. Thus, as a prelude to process-based investigations, the primary objective of this research is to begin the assessment of the presence of multicycle OC (fossil plus younger terrestrial material) on subduction margins beyond the mid-slope. The Hikurangi Margin nearshore environment is well studied, and subduction dynamics/sedimentation provides the ideal research site for further investigation of this unexplored portion if the global C-cycle. Preliminary assessment of the nature and distribution of multicycle-C at this site will be important for planning future GeoPRISMS-related studies of C cycling and subduction dynamics.

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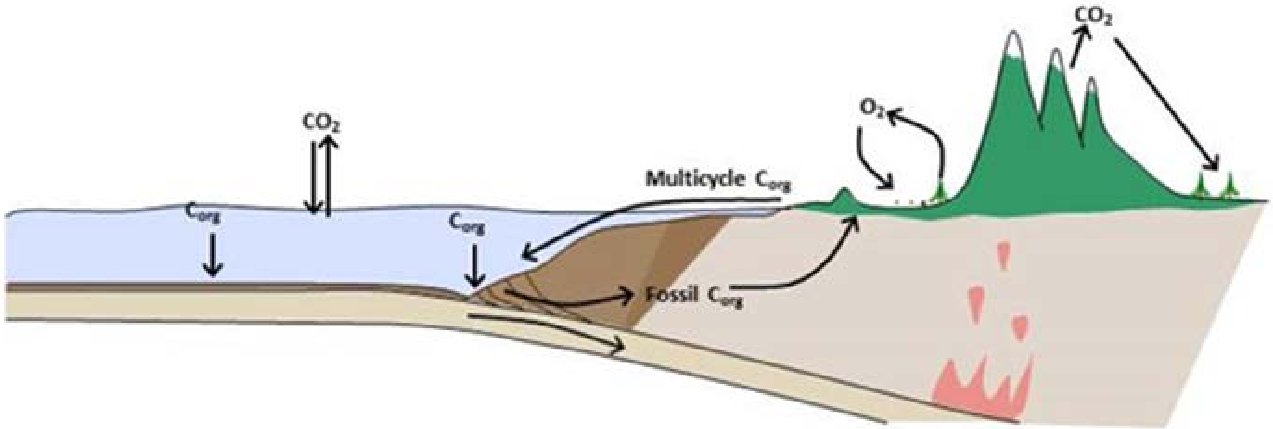

Figure 1. The active margin C-Cycle. Accretion, uplift, and erosion of sedimentary rock on the continent bring previously buried OC to the surface. If mass wasting is sufficiently rapid, as is the norm on these margins, the exposed fossil C is recycled into the sedimentary system thereby avoiding oxidation in subaerial outcrops. The recycled fossil C is blended with younger material as sediments move across the surface.

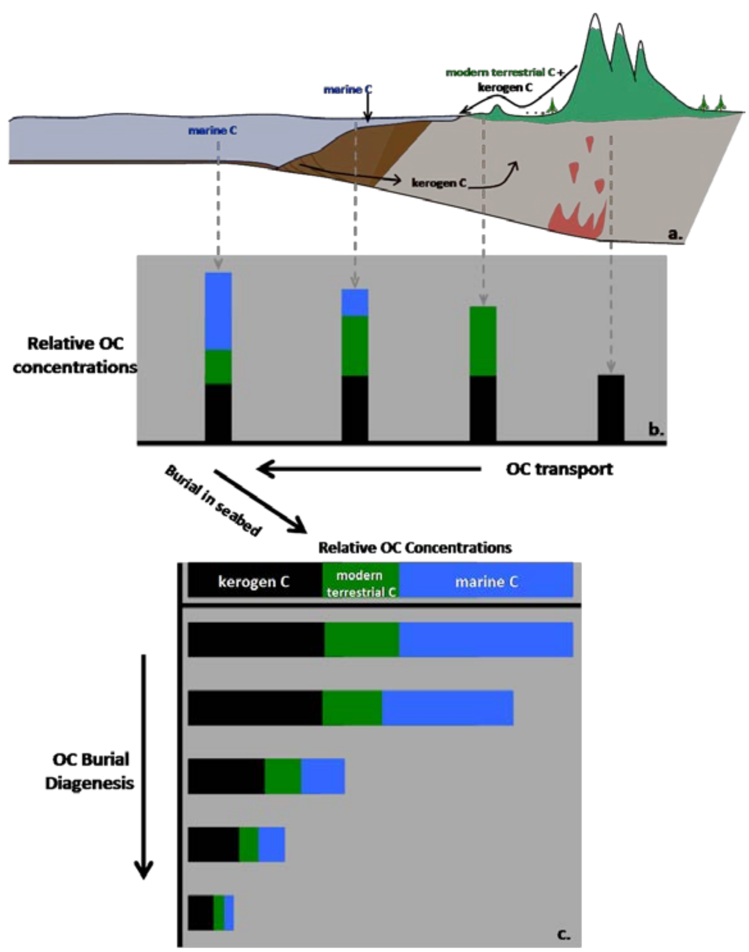

Figure 2. The active margin and accretionary wedge carbon cycle (a). Kerogen formation begins with the diagenesis of organic matter. Tectonically uplifted kerogen will combine with modern terrestrial sources and the mixed pool will be transported by rivers to the marine realm, where the marine pool of organic carbon will be added prior to burial, while terrestrial carbon is concurrently lost (b). During burial and diagenesis marine and modern terrestrial carbon will be lost, while kerogen will be preferentially preserved (c).