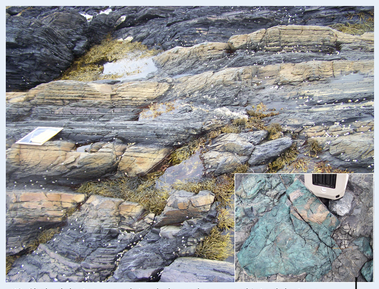
The Yellow Point formation and its relationship to peridotite carbonation, Lobster Cove Head, western Newfoundland

Douglas N. Reusch, University of Maine at Farmington
John W.F. Waldron, University of Alberta

P5. Lower Head Formation. Scoured sand-filled channel (top); block of dolostone breccia (lower left); detrital chromite sand grains (lower right).

P4. Upper part of Yellow Point formation. Dolostone more abundant than shale. Locally, the dolostone beds are burrowed (inset).

P3. Green and black shales of Unit IV exposed in Campfire Cove. Limestone below. Inset shows phosphatic brachiopod from dolostone bed.



P2. Shale-dolostone couplets, shale grades upward into dolostone. Inset shows green glauconite(?) from chert unit (top of P1).

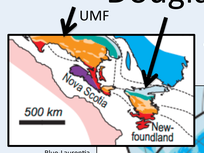
P1. Ribbon limestone-shale and limestone breccia (top of Cow Head Group) overlain conformably by black chert (base of Yellow Point formation).

Introduction

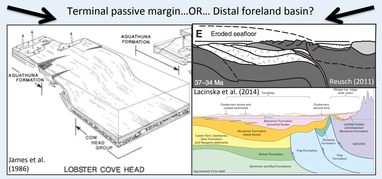
At Lobster Cove Head, chromite sand grains in the Lower Head Formation document the erosion of mantle peridotites when, during the Ordovician Taconic collision, Laurentia lifted up the leading edge of the oceanic plate. Immediately subjacent strata include distinctive ferruginous dolostones, shales, and cherts here referred to as the Yellow Point formation (YPF). Could these dolostones be related to the dissolution of the same peridotites that released the chromite grains?

The YPF conformably overlies distal passive margin strata of the Cow Head Group. Does the YPF represent the terminal passive margin (James et al. 1986) or, alternatively, the distal part of the Taconic foreland basin? In Oman, peridotite debris shed from the Samail ophiolite has been diagenetically converted to dolomite, forming a rock called barzamanite (Lacinska et al. 2014). Is it possible the YPF dolostones constitute the first example of (resedimented) barzamanite to be recognized outside of its type locality?

A link to peridotite carbonation would be of considerable interest to efforts to both decipher mechanisms of past climate change (e.g., Reusch 2011) and also ameliorate future climate change (Kelemen and Matter 2008). To address these questions, reconnaissance mapping of Lobster Cove Head was done by DNR on 2014 August 7-8.



Blue-Laurentia, Green-Taconic arc, Orange-Ganderia, Red-Avalonia, Purple-Meguma, Pink-Gondwana



Stratigraphy and sedimentology

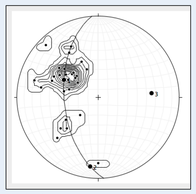
The YPF comprises a unique sequence of Lower-Middle Ordovician yellow-weathering dolostones, minor limestone, black to green shales, and black to green cherts within the ancient continental margin of western Newfoundland. Its basal chert member conformably overlies Bed 10 limestone conglomerate of the Shallow Bay Formation, Cow Head Group (James et al. 1986). The YPF is sharply overlain, possibly disconformably (P5), by chromite-bearing green sandstones of the Lower Head Formation.

James et al. (1986) referred the YPF shales and dolostones to their Units IV, V, and VI (see depth-age plot) of their Lobster Cove member, Shallow Bay Formation, Cow Head Group. Whereas the basal chert (their Unit III) has an easily-mapped sharp conformable contact on limestone conglomerate/breccia (P1), their Unit III-IV contact is gradational from cherts (P1) to interbedded shales and dolostones (P2). In general, with the exception of a prominent horizon of shale and minor limestone (P3), the relative abundance and thickness of dolostone beds increases towards the top (P4).

Several hypotheses have been proposed for the origin of the dolomite (e.g., Stevens 2003), depending on whether it was primary or replacement, formed at the surface or within the sediment, first cycle or detrital, and whether the source of Mg^{2+} ions was local (ophiolite) or not (global ocean). James et al. (1986) describe a "densely packed mosaic of euhedral dolomite rhombs, generally zoned, with distinctive anhedral to subhedral cores. Angular quartz and feldspar grains are common throughout. This type of dolomite... (Coniglio 1985) is interpreted as overgrown detrital dolomite derived originally from a shallow-water platform."

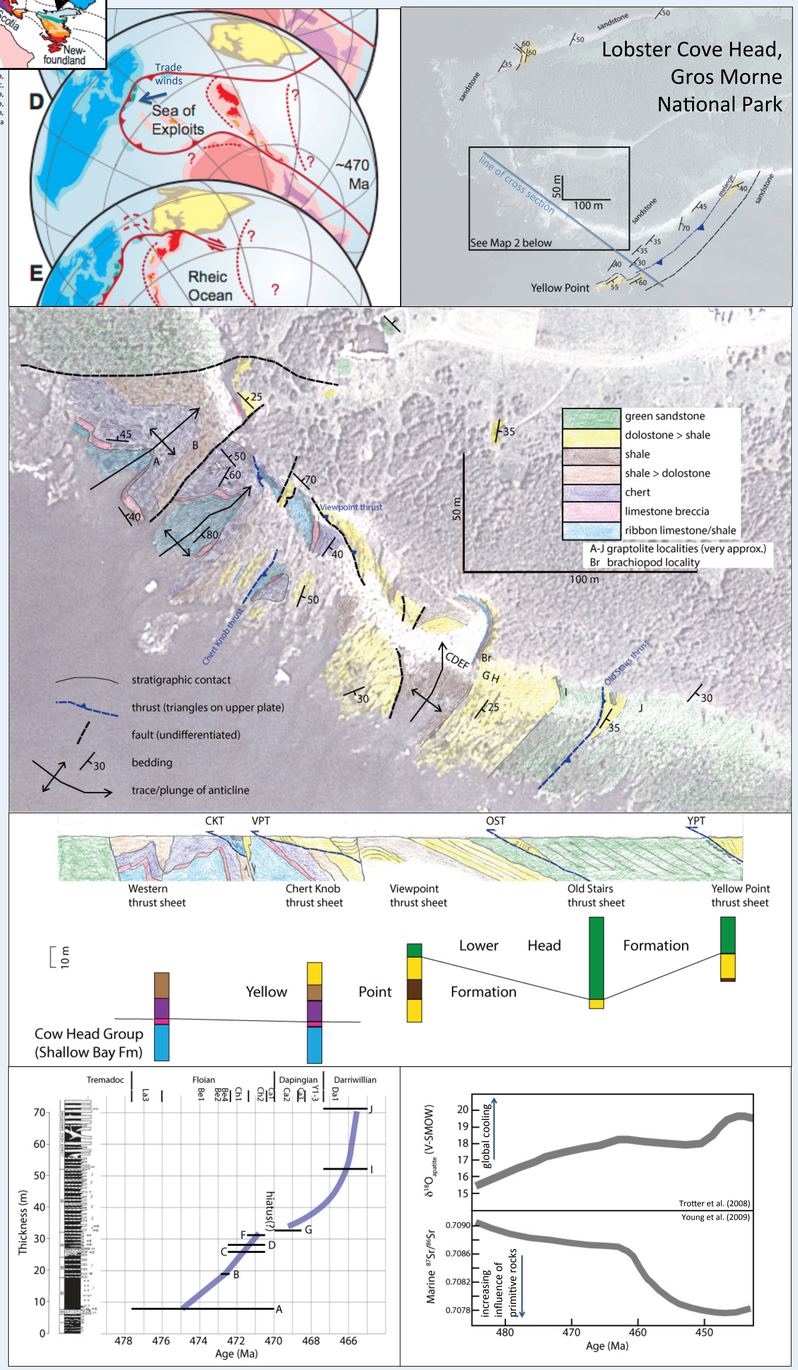
Graded beds of shale overlain by dolostone (P2) are common above the basal chert member of the YPF. Could these reflect climate cycles ranging from humid (clays, serpentinization of ophiolite) to dry and windy (e.g., Persian Gulf during the Pleistocene)?

Burrows are present in some dolostone beds (P4 inset), where they remain uncompacted due to early silicification (James et al. 1986). In addition to multiple graptolitic horizons, a phosphatic brachiopod was located in a dolostone bed (P3 inset).



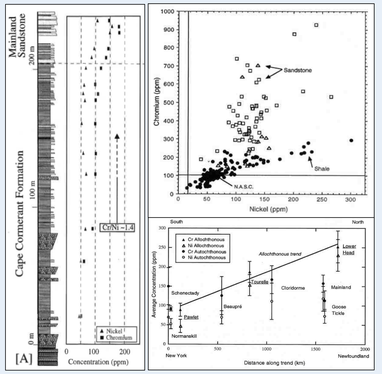
Structural geology

Lobster Cove Head hosts a large km-sized raft of relatively intact strata within the Rocky Harbor Melange that separates autochthonous rocks of western Newfoundland from the Humber Arm Allochthon. These generally SE-dipping strata (see stereoplot) experienced at least three generations of deformation related to 1) emplacement of the allochthon, 2) subsequent extension, and 3) later folding. James et al. (1986) recognized both low angle and high angle faults but viewed the exposure as essentially one conformable section, an interpretation permitted by their graptolite chronology. This study recognizes four thrust faults, from east to west: the Yellow Point thrust (YPT), Old Stairs thrust (OST), Viewpoint thrust (VPT), and Chert Knob thrust (CKT). Except for the VPT, these thrusts place older strata over younger. The anomalous young-on-old VPT, along with map-scale boudinage of a limestone conglomerate bed and chert strata, requires an interval of extension (Waldron et al. 1988) that pre-dates the map-scale anticlines in the western thrust sheet. Along the OST, Lower Head sands were injected as dikes and sills through the YPF dolostones. Along the YPT, lozenge-shaped lenses of limestone and shales are highly sheared, the shales in Woody Cove displaying phacoidal cleavage characteristic of mélange. An east-plunging anticline at the base of this thrust sheet just northeast of Yellow Point may correlate with Waldron et al.'s F3 generation.



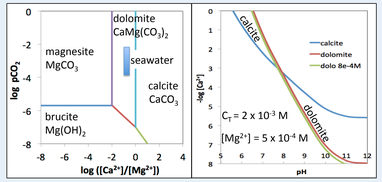
Geochemistry

Garver et al. (1996) analyzed shales in the Taconic foreland basin for chromium and nickel. They found that Cr/Ni ratios of 1.4, close to that of the ophiolitic ratio 1.6, occur well below the first sands. Note that of all the formations sampled, the Lower Head Formation contains the highest Cr and Ni values.



The activity plots below show how dolomite is stabilized by both high Mg^{2+}/Ca^{2+} ratios and high pH, both of which would be enhanced by the dissolution of olivine that is implied by the detrital chromite grains.

$$Mg_2SiO_4 \;\&\; 2H_2CO_3 \Rightarrow 2Mg^{2+} \;\&\; 2CO_3^{2-} \;\&\; H_4SiO_4$$



Discussion and Conclusions

Based on a preliminary analysis of the Yellow Point formation, the suggestion that its ferruginous dolostones may somehow reflect the carbonation of nearby peridotites should be taken seriously.

1) Elsewhere, ophiolitic Cr/Ni ratios in shales occur well below the first chromite-bearing sands.
2) High dissolved silica, implied by uncompacted silicified burrows, is difficult to explain in an oligotrophic carbonate platform setting.
3) Coarsening/thickening-upward trend from pelagic (chert) through hemipelagic (clays) to detrital (dolomite) suggests a contractional (foreland) rather than extensional basin.
4) Similar trend from west to east in thrust sheets suggests an eastern source.
5) Trade winds would have delivered aeolian dolomite from the east.
6) The James et al. (1986) terminal passive margin model requires significant along-strike variation, which may be unrealistic.
7) Extensive dissolution of basic and ultrabasic rocks uplifted during Taconic collision helps to explain global cooling and decreasing marine $^{87}Sr/^{86}Sr$ ratio during this interval.

Obvious "next steps" include:
1) Sample and analyze YPF shales for Cr and Ni.
2) Continue detailed stratigraphic and structural analyses.

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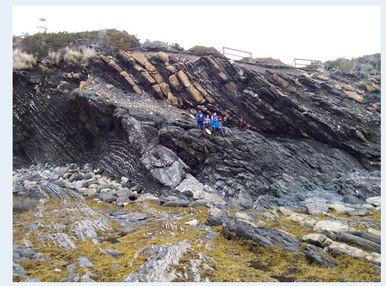
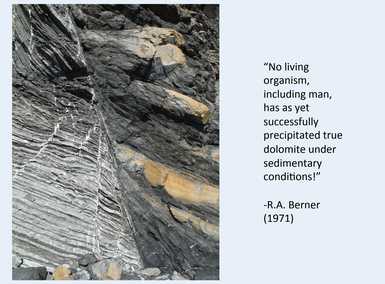
P6. Small-scale extensional faults in dolostone

P7. Yellow Point thrust (YP dolostones over LH sandstone). Note lens of limestone (ls) in sheared shale along the thrust.

P8. Yellow Point formation dolostones injected by dikes and sills of Lower Head Formation sandstones, basis for Old Stairs thrust.



P9. Viewpoint thrust places Yellow Point formation dolostones-shales over Cow Head Group.



P10. Late normal fault. Younger dolostones-shales on older ribbon limestones.

"No living organism, including man, has as yet successfully precipitated true dolomite under sedimentary conditions!"

-R.A. Berner (1971)