Evolution of the Tyee Formation in the Cascade Coastal Mountain Range in Western Oregon

By John Matylonek

Along Highway 20 from Newport Oregon to Corvallis, Oregon a number of very recent road cuts have exposed stratigraphy that help explain the evolution and growth of the continent westward by a couple of accretionary events. That is, island arcs, like present day Japan, which have collided with a past coastline, that was located nearer to present day Idaho. This is what I have found out since observing, measuring and collecting some samples and viewing the overall structure and doing some basic background research.

I have always driven past these formations with the simple idea in mind that they were turbidite layers, essentially underwater sediment avalanches, formed in submarine canyons as a result of seismic events. So, when this assignment came along, the opportunity to investigate these sedimentary layers further was a natural choice, particularly since a new highway has exposed significantly more of the sequence and much more research has been done to explain their origin.

Two locations of the Tyee formation were examined. **You can input this latitude and longitude in google maps and view the street level to see the formation.**

The one located at

44.627778 -123.763611

Elevation 1170

Was probably indicative of the lower sub-part of the formation member.

The second location at:

44.6362135 -123.7959979

Elevation 1482

Is higher up the stratigraphic column is indicative of the higher sub-part of the formation member.

That is a 312 foot difference. Yet the entire Tyee Formation is 1 km to 1.9 km (0.6 Mi to 1.18 mi) (3168 ft to 6230 feet) thick as it extends south towards Klamath Falls. So this sequence only

represents the very oldest of the Tyee Formation called the Tyee Mountain member. There is only a minor deformation folding of the Tyee Formation so this deduction probably holds. Here is the diagrammatic cross section.

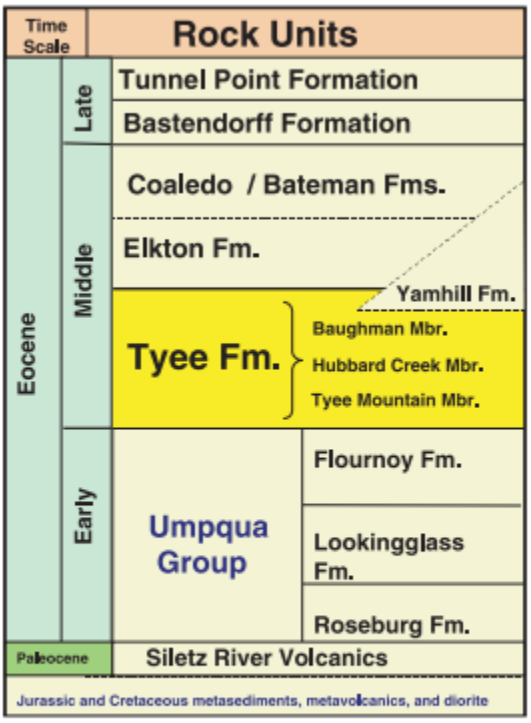


Figure 2. Stratigraphic column for the Paleocene and Eocene rocks of the Tyee and Umpqua Basins. Modified from Chan and Dott (1983), Heller and Dickinson (1985), and Ryu and Niem (1999).

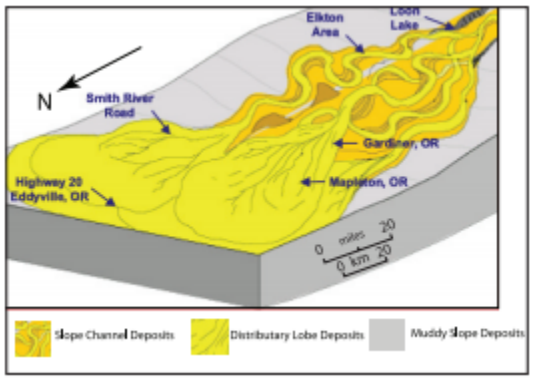
The **Eocene** Epoch is a geological epoch that lasted from about 56 to 33.9 million years ago (mya). It is the second epoch of the Paleogene Period in the modern Cenozoic Era. The **Lutetian** is, in the geologic timescale, a stage or age in the Eocene.[4] This is the time of the deposition of the Tyee Mountain Member. It spans the time between 47.8 and 41.2 Ma. The Lutetian is preceded by the Ypresian and is followed by the Bartonian.[5] Together with the Bartonian it is sometimes referred to as the Middle Eocene subepoch (Wikipedia)

The classical facies interpretation

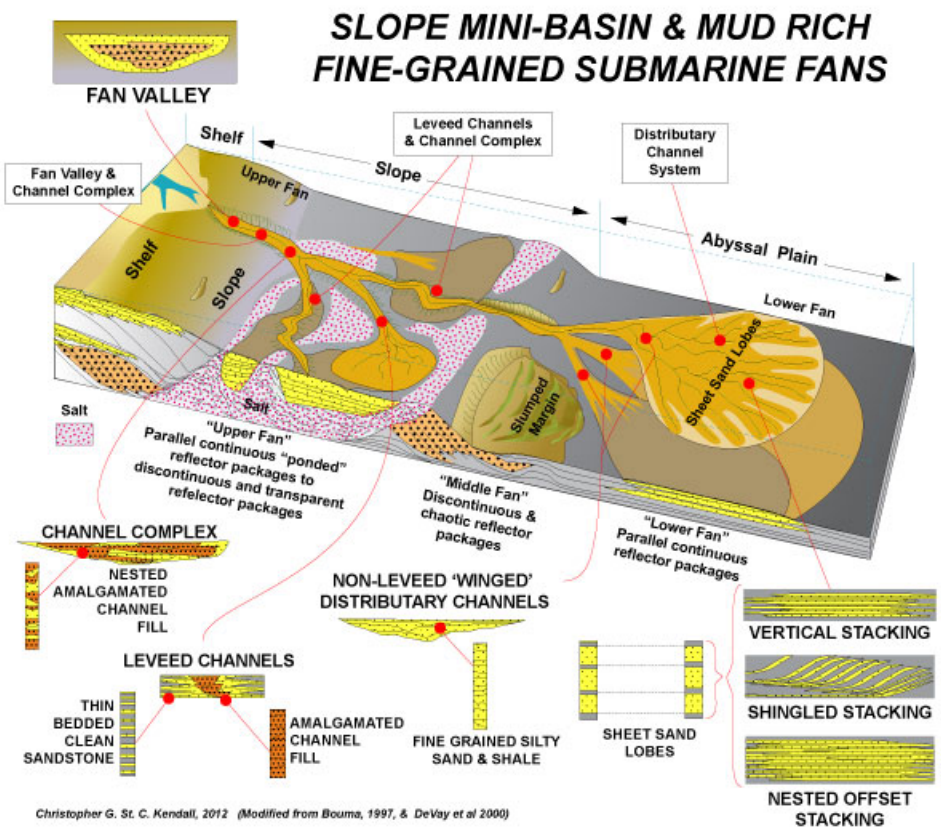
When mountains erode they deposit sediments in a predictable pattern called facies. That is in characteristic geological structures and biogenic evidence of the environment of deposition. Closer to a land based mountain we have more potential energy (steep slopes), dry alluvial fans, that gradually transition to higher energy to slower energy river deposits and delta deposits and eventually to submarine deposition on shallow shelves to steeper underwater canyons and finally the flat ocean floor. All these environments deposit sediments that are distinct to the

energy and nature of the deposition and form sedimentary rocks that have recorded those different depositional environments.

The Tyee Formation was deposited on an ancient submarine fan to ocean floor transition whose energy profile parallels that from a land based steep mountain to river plain transition.



The following model clarifies the Tyee formation depositional pattern in the Abyssal Plain.



The Tyee Mountain Member as exposed on Hwy 20 west of Corvallis would be part of either the “Middle Fan” or Lower Fan” facies transition in the Abyssal Plain. The questions regarding this

member is whether it is part of the “proximal” (closer) or “distal” (further) fan, as well as why there is not thinly bedded, ripple laminated sandstones but instead thicker massive sandstones interbedded with muddy sandstones and mudstones. And, finally, the origin of the sediment (which mountain range) source for this member.

Descriptions of Rock Types Found

I sampled four specimens of the Tyee Mountain member that represent, in part, specific depositional events... and I found one very strange anomaly, a diorite, that will help illustrate the source of these sedimentary rocks. There are many more nuanced hybrids of the textures in the member but that would not serve our educational purpose here.



The arkosic massive sandstone is light, homogenous, fine to medium grained and highly amalgamated. I found flute marks on the lower surfaces of the beds.

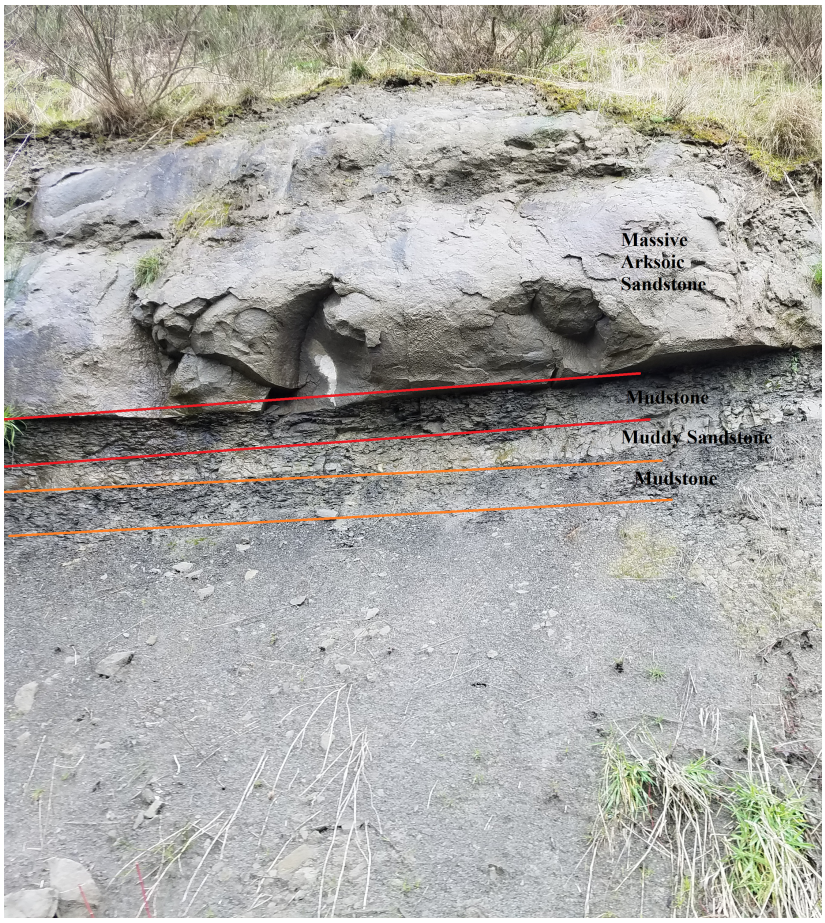
The darker muddy organic rich sandstone layers are also fine to medium grained less amalgamated (crumbly) and one can see particles of darker inclusions and larger crystals.

The very-fined grained gray siltstone is less massive and occurs in thinner beds between the arkosic and muddy sandstone layers.

Finally, the undifferentiated mudstone, without water, loses integrity and structural definition and thicker ones form muddy sl +opes along the outcrops.

Why and how I found an igneous diorite near the member is inexplicable (did a professor bring it along as a prop for a class?) unless it really is part of the Idaho batholith that later did become a source of the sediment of this formation. Only radioactive isotopic measurements could confirm this.

Bedding structures



Massive fine grained to medium grained arkosic sandstone

Fissile amalgamated mudstone
Carbon-rich sandstone

Mudstone siltstone



A more complete section of Tyee Mountain member. I measured the Dip of 08 deg and Strike Azimuth 340 deg using the Fieldmove Compass Clinometer. That is, the direction of inclination from Southeast to Northwest.

Sole marks

The underside of the massive sandstone bedding provides evidence of the different densities and natures of the bedding including direction of flow from lineations derived from debris being dragged in direction of flow. Here a nice groove mark from lower left to upper center is exactly in direction of strike and dip of the overall bedding.



Bulbous load casts result from higher density intrusions into the underlying softer sediments.

The Tectonic Origin of the Sediments

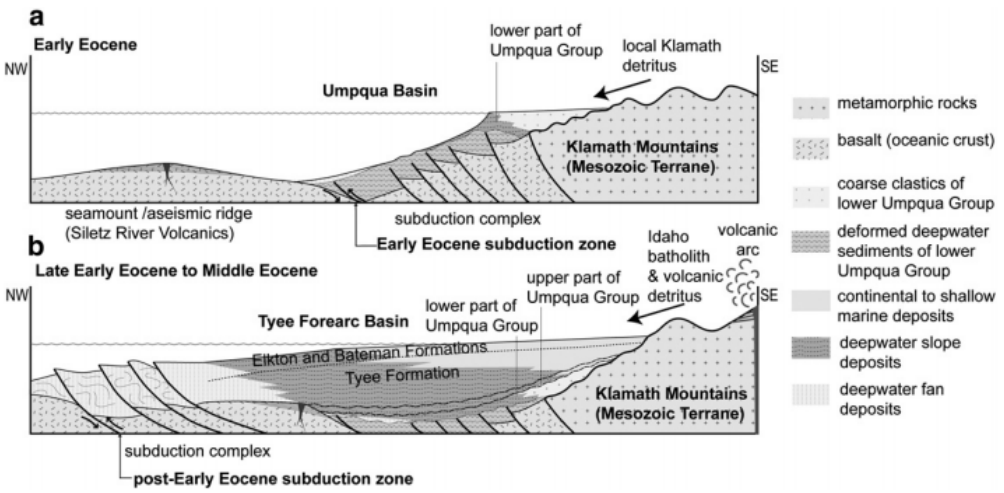


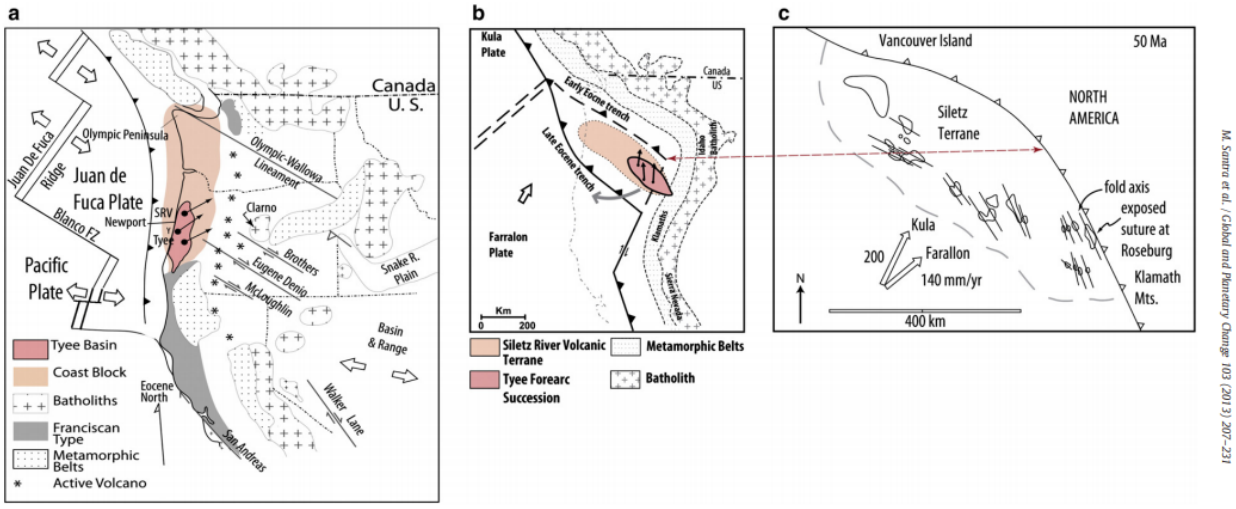
Fig. 4. Depo-tectonic model for the Tyee forearc Basin. a. Early Eocene subduction and deposition of the Umpqua Group. b. Arresting of subduction along early Eocene trench and formation of a new subduction zone in late Early Eocene resulting in accretion of the Siletz Terrane followed by late early Eocene to middle Eocene forearc sedimentation (modified from Heller and Ryberg, 1983).

The story of how these sediments got here to form these bedrock layers is an interesting exercise in the dynamic earth plate and terrain movements. From the evidence of age and composition of various minerals in the sedimentary layers one can compare that with present

day mountains geological structures. It turns out that initially the source sediment of the older underlying Umpqua group originated from the Klamath Mountain Mesozoic Terrane. But then the depositional basin changed to include more sediment from the more eastward source igneous Idaho Batholith. The mechanism of this change in source area was the displacement and rotation of the subduction zone that drives the buildup of the volcanic cascade mountain chain.

Diagram A above shows the setup of the basin before the deposition of the Tyee. The seamount aseismic submarine ridge is akin to the present day Japan island arc system whose subduction zone is east of the arc. The evidence suggests that the basaltic crust failed to plunge into the mantle because of more buoyant magma seamount build-up and submarine seamount collision with the continent plate margin “plugged” the system and the set-up of a new subduction zone west of the previous.

There was a rotation from NW to N (map B below) of the subduction margin changing the source of the sediment of the Tyee Formation from the Klamath Falls metamorphics to include granitic igneous diorite of the Idaho batholith. (that is why I am astounded to have found diorite cobble along side the formation???).



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Fig. 3. Some important tectonic elements of the present-day western North America and a model for accretion and post-Early Eocene rotation of Siletz River Volcanics (SRV). a. Important tectonic elements of western North America in relation to the present-day orientation of the Tyee Basin and it's volcanic basement (Coast Block), outcrop area of the relative undeformed clastic sediments of Tyee Basin is marked; note, the orientation of recorded magnetic field direction from Paleocene/Early Eocene volcanics indicated by black arrows suggesting post-Early Eocene Rotation of more than 65°. b. Model for accretion and rotation of the Siletz River Volcanics (SRV), showing possible tectonic configuration of the volcanic terrane, which was accreted on to North American plate in Early Eocene (~50 Ma) following an arrest in subduction along an Early Eocene subduction zone, post-Early Eocene rotation clockwise rotation occurred around a pivot point near the northern end of the accreted terrane (the black arrows indicate possible original orientation of the magnetic field). c. Possible orientation of the suture zone in Early Eocene (~50 Ma) (after Wells et al., 2000).

Map A shows the current situation with the subduction of the Juan de Fuca plate offshore and the Siletz River Volcanics (Siletz Terrane in map c) at the base of the Umpqua Group and Tyee Formation. In the early Eocene (map b), the situation was that the subduction zone was more eastward and the Siletz ocean floor crust (terrane) formed the basin of the Tyee Formation with predominantly metamorphic Klamath Fall sediments. However, when the Siletz Terrane “stuck” and arrested the subduction, the zone rotated (map b) westward and a new cascadia volcanic arc brought in Idaho granitic source sediment into the formation.

Environment of deposition explaining facies observed

There is some confusion as to why the Tyee Mountain member does not contain mostly ripple laminated sandstones part of the distal abyssal plain fan as described by Mutti (1977). The Tyee Mountain member contains the arkosic massive sandstones capped by muddy debris rich siltstone and mudstone. This sequence has been interpreted as being turbidite flows in which the fluid turbulence suspends the particles of different sizes and allows the differential settling of particle size as the flow wanes. However, slurry flows are particle debris flows driven by the velocity of the fluid not the turbulent lift of the fluid. My hypothesis is that the new depositional environment driven by a nearer volcanic range created a more highly energetic and dynamic volcanic arc system allowed for steeper submarine slope and slurry debris flows rather than turbidite flows. Also, the dynamic erosion and volcanic build-up of the new source area contained would provide different river systems and associated sediments, alternating between Klamath Falls metamorphic, new volcanics and the igneous Idaho batholith.

References

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Reconnaissance Petrographic Gross Section of the Idaho Batholith in Adams and Valley Counties Idaho. By DWIGHT L. SCHMIDT * CONTRIBUTIONS TO GENERAL GEOLOGY GEOLOGICAL SURVEY BULLETIN 1181-G https://pubs.er.usgs.gov/publication/b1181G

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