GEOLGY OF THE NORTH CASCADES
"Geologic Crossroads of the Pacific Northwest"

Skagit River Field Trip
North Cascades National Park

J. Figge 2010
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The Skagit River is the largest river system draining the North Cascades Mountains of Washington. Rising on Allison Pass in British Columbia, it flows some 150 miles (240 km) to the ocean, draining some 1.7 million acres (6900 km²) of rugged mountainous country along its way. Along that route it serves as the centerpiece of the spectacular North Cascades National Park, it generates much of Seattle’s electrical power, it nourishes some of the most bountiful farmlands in the region, and it serves as home to some 100,000 people.

The lower Skagit floodplain is a rich agricultural province, home to the American flower-bulb industry. In the spring, it is carpeted with fields of tulips, daffodils, and a variety of other species, destined for world markets. Above, the lower valley is a pastoral setting of small farms, green pastures, and small towns, nestled along the meandering river in its broad floodplain. Higher up, it flows down a deep valley cut into the western flanks of the North Cascades, rising into a spectacular canyon which cuts into the very heart of the range. Above, it emerges from a unique intermontane province, surrounded by towering mountains on all sides. Along this entire route, it traverses some of the most spectacular country in the entire Pacific Northwest.

Along that same route, this region provides one of the most illustrative geologic settings in the entire Pacific Northwest. The modern topography of the province is a spectacular showpiece for the recent processes of glacial erosion, on both a local and continental scale. The rocks of this region, by contrast, tell the much older story of how this province was assembled over the course of geologic time. Exposed by the processes of uplift and erosion, the rocks here offer a uniquely illustrative venue on that course of regional geologic evolution.

For all of these reasons, the Skagit River has been a popular geologic field trip since the North Cascades Parkway (SR 20) was opened in 1973. Among day-trips out of the Puget Sound region, no other venues come close to offering such an illustrative perspective on the geologic evolution of the Pacific Northwest. That course of geologic evolution is preserved in a rock record cast into some of the most spectacular scenery to be found anywhere in the region, making it one of the premier regional field trips.
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## The Skagit River Field Trip

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Figure A (Above)
Physiographic map illustrating the regional extent of the North Cascades Mountains. For a variety of reasons, the southern end of the province can be placed at Snoqualmie Pass.
The North Cascades is the most rugged mountain range in the coterminous United States, a wilderness province so formidable that it deterred most explorers into the middle of the twentieth century. From its deep, glacially-carved valleys to its steep ice-mantled summit crests, it is the most heavily glaciated mountain range in the country, south of Alaska. As such, it is a truly spectacular illustration on how glaciers sculpt the landscape, and on a somewhat more compact scale than is typical of most alpine ranges. Rising above (what were once) the great temperate rainforest of the Puget Basin, they also offer a graphic vantage on how ecologic communities reflect the changing environmental conditions across the width of the range. These are the unique natural qualities for which this region was originally preserved as a national park.

At the same time, the varied rocks which comprise this spectacular province tell a much older story, a story which stretches back hundreds of millions of years into geologic time. This is the story of the geologic evolution of the Pacific Northwest, one of the most persistent enigmas in North American geology. Over the last two hundred million years, that course of geologic evolution has included the westward growth of the continent by over 500 km, from a shoreline originally located near modern-day Spokane. This has happened as the westward-advancing continent has collided with various island-groups and other oceanic rocks, adding them to the continental margin. Over that same period, the evolving continental margin hosted a succession of volcanic, mountain-building, and other episodes, which have further shaped the geologic fabric of the province. In the end, the range offers truly world-class vantages on these dynamic and fundamental Earth processes, along with spectacular illustrations on how this region has been assembled over the course of geologic time.

**Figure 1** (Above) The Southern Picket Range, a rugged sub-range north of the Skagit River and east of Mt. Baker. These peaks have been extensively carved by alpine glaciers. National Park Service Photo.

**Figure 2** (Right) Mount Baker, from the Yellow Aster Meadows area to the north. The rocks in the foreground are among the oldest in the range, dating from over 450 million years ago. Mount Baker is the youngest feature on the landscape, having accumulated largely over just the last 50,000 years.
Beyond the truly graphic reflection they afford on the geologic past, these mountains occupy a truly unique geographic and climatologic position along the Pacific Coast here. While they are not tall or massive peaks by alpine standards (reaching to a maximum of about 3 km), they rise from very deep valley footings, and have been deeply sculpted by the processes of glacial erosion. Unlike any other range south of the Canadian border, these mountains are capped by a distinct arctic-alpine zone, occupied by a (diminishing) regional ice-cover. This glacial cover is owed to the large amounts of precipitation visited upon this maritime range, accumulating the heaviest snowfalls recorded anywhere on the planet.

Beneath that arctic-alpine zone, a narrow band of subalpine parkland often intervenes above the forested slopes below. In this region, that parkland zone occurs between 5500 and 7000 feet, and may include herbaceous meadows, heather slopes, or (on the east side) open grasslands. On the west side, this subalpine parkland yields to forests of hemlock, fir and cedar below. Few mountain ranges in the world afford such a compact illustration on this series of ecosystems, transitioning from forest to alpine settings over what is often just a few hundred feet. Within that few hundred feet, the North Cascades boasts some of the most beautiful subalpine parklands in the world,affording world-class venues on some of the most spectacular scenery in North America.

**Figure 3 (Above)** Rock, ice and subalpine meadows. The meadows in the foreground are heather, typical of the cover on igneous rocks like the granitic varieties seen here. The dark green meadows in the background are lush herbaceous species, growing on iron-rich metamorphic and metavolcanic rocks. This region is part of the Eldorado Massif, a major sub-range in the Skagit drainage.
Finally, with their proximity to the urban centers of the Puget Sound Basin, these mountains have afforded the local population with a unique variety of opportunities for recreation and adventure. Most significantly, this region is considered the birthplace of American mountaineering, an endeavour dating from the 1860’s. This rugged wilderness province of ice-mantled summits has challenged generations of mountaineers, and has produced legions of world-class climbers. For the somewhat less-ambitious, the region features some of the most spectacular backpacking to be found anywhere in North America. While we don’t claim to have invented the sport, we showed the world how to do it right (as a member of REI).

Figure 4 (Above) Liberty Bell Mountain and Early Winters Spires (Washington Pass), a popular rock-climbing objective.

Figure 5 (Below) Black Peak, one of the major peaks astride the North Cascades Highway.
Prior to the arrival of European settlers, the lower Skagit Valley was the domain of two native American groups, the Upper and Lower Skagit bands. It is likely that the predecessors of these cultures settled in the valley not long after the continental ice-sheet retreated from the region. These peoples enjoyed a riverine culture centered on the salmon runs and prairies along the river floodplain. They traded extensively with the neighboring bands, including the Nooksack and Chilliwack to the north, and the Sauk- Suiattle to the south. Archeological evidence from the upper Skagit suggests that this area was occupied as early as 8000 years ago, and that it was likely a common hunting area among the local tribes. A large proportion of this population died off in epidemics over the 1830’s and 1840’s.

The first permanent settlers from the east arrived in the 1850’s, settling coastal communities around Puget Sound. La Conner and Utlsalady were the original towns on the Skagit Delta, where settlers were attracted by fertile land and abundant water. Mount Vernon was not established until 1877, while Sedro (-Woolley) was originally founded in the following year. These towns served a growing agrarian community in the region.

Upriver, the towns Lyman and Hamilton were originally founded as logging towns, Hamilton in the early 1890’s, Lyman at the turn of the century. For over a half a century, mills in these towns ran on the rich stands of timber flanking Mount Baker and the western slopes of the Cascades. Over much of its early history, the economics of this region were driven by timber, fishing and agriculture.

The town of Concrete, at the junction with the Baker River, was founded at the turn of the century. Originally

Figure 6 (Above top) The North Cascades Photo by E. Andersen

Figure 7 (Above) The Skagit Gorge, prior to the construction of Gorge Dam in the 1930’s. The bridge above is part of the trail which used to climb the canyon before the railroad line was established. NPS Photo.
known as “Baker”, it changed its name in 1906 when the Washington Portland Cement Company located in the town. For sixty years this enterprise produced concrete for the dams on the Skagit, and features around the Puget Sound region. Over that period, the valley in this area was perpetually covered in a gray dust of limestone powder. The limestone quarry played out in the late 1960’s, but the town still holds on to its endearing name.

The lure of gold brought the first explorers to the upper Skagit. Various gold rushes up the Skagit and Cascade Rivers brought prospectors in the 1880’s, 1890’s and early 1900’s. An early center, Goodells Landing, was established at modern – day Newhalem in the early 1880’s. In 1890, the town of Marblemount was said to have a population of some 1500 people, largely tented, as a base for prospecting in the surrounding mountains. By that date it was possible to take a steamer up the river as far as Birdsvig. The various gold rushes largely waned within a few years of the initial furor, but development continued in the Cascade River area over the early 1900’s.

Above modern-day Newhalem, the precipitous Skagit Gorge deterred all but the most adventurous prospectors. Here the Skagit ran through a deep canyon with steep walls and formidable cliffs. A crude route scrambled up through the ledges, across faces and over airy bridges, but it was a notoriously perilous route. It was impassible to stock, constantly in disrepair, and was generally avoided by the prudent. The more practical route, long used by native peoples, ascended the Cascade River to the crest of the range, then followed Thunder Creek back down to the upper Skagit.

This changed in the 1920’s when Seattle City Light began development of the upper Skagit for hydroelectric power. From the company town of Newhalem, a narrow-gauge railroad was established up the Skagit Gorge, permitting development of Gorge Dam (1924) Diablo Dam (1936) and Ross Dam (1952). The waters of Gorge Lake are diverted into a two-mile set of tunnels through

**Figure 8** (Above) The “Devils Corner,” part of the notorious trail which climbed the Skagit in the late 1800’s. Most travelers avoided this perilous route.

**Figure 9** (Right) Construction of Diablo Dam, during the 1930’s. Note the steam shovel. These dams were major engineering feats in their time. When completed, Diablo Dam was the highest dam in the world. Seattle City Light Photo.
solid rock to the powerhouse in Newhalem. As a result, the riverbed is often dry between Gorge Dam and that point. These dams provide about a third of Seattle’s electrical power, at some of the least expensive rates in the country.

At the same time, the lakes impounded in the upper Skagit forever changed the ecosystems of this very unique Intermontane setting. The valley here was formerly a winter refuge for innumerable species, and a major regional migration route. All of this was changed when Ross Lake was flooded in the early 1950’s, forever altering this unique natural setting.

Over the strenuous objections of local economic interests, the upper Skagit region was preserved as part of the North Cascades National Park in 1968. The north cross-state highway (SR 20) was under construction at the time, as was re-titled the “North Cascades Parkway.” That road was opened in 1973, opening the region to the motoring public. Since that time, the region has acquired an international reputation as a realm for backpacking, mountain-climbing and wilderness adventure of various sorts. With the subsequent decline of the timber industry, tourism has in part made up for the loss of that local industry.

Figure 10 (Above) Diablo Lake, formed with the construction of Diablo Dam in 1930. While generating inexpensive pollution-free electricity for Seattle, it forever changed the unique ecosystem which used to exist here.
Backpacking, mountaineering and other adventure sports have a long tradition in these mountains, which afford a uniquely accessible setting for residents of the Puget Sound region. Outside of Alaska, it is the only range in the country which offers truly alpine climbing opportunities.

Recreational use of the province skyrocketed in the 1970’s with the publication of the first guidebooks to the mountains here. Over the last two decades, commercial outfitters have become an increasing presence, catering to national and international clientele. In numerous areas, it has been necessary to restrict the number of visitors.
Generalized geologic map of the central portion of Washington State. It can be seen that the North Cascades are a geologically distinct province from the southern portion of the range.
INTRODUCTION

The North Cascades region provides excellent venues on a variety of geologic processes, but is a truly outstanding setting for considering the effects of local and continental glaciation, and for illustrating the broader course of regional evolution over the span of geologic history. For those without much background in the geologic sciences, the story of how this region has been sculpted by glaciers over the recent ice-ages is the most obvious theme on display here. Outside of Alaska, it is the most illustrative alpine landscape in the country, and a powerful testament to the forces of glacial ice.

With just a bit of geologic understanding however, this region is revealed as the nexus of a truly intriguing story of geologic evolution, a story which stretches back nearly 200 million years. Over that vast expanse of geologic time, the Pacific Northwest was assembled from sections of volcanic-island and ocean-floor rock, overprinted by a series of volcanic chains, deformed into a succession of mountain ranges, injected with generations of granite-type rocks, all serving to extend the edge of the continent some 500 km to the west, from a shoreline originally located near present-day Spokane. Through many of these varied events and episodes, the North Cascades region has occupied a central position. Accordingly, it offers a uniquely complete perspective on this remarkable course of regional geologic history.

The modern Cascade Range is the product of an episode of regional folding which started 5-7 million years ago, and continues to date. The uplift of the northern end of the range appears to have started a few million years earlier, as a southern element in the modern Canadian Coastal Range. These developments, it should be emphasized, occurred without regard for the accumulated geology of the province. The recent ice-ages commenced some 2.5 million years ago, in a cycle which last ended 13,000 years ago, and continues to date. The modern volcanoes which cap the larger range have largely accumulated over the last 50,000 years, and are the most recent features on the landscape.

While it is possible to consider this course of regional geologic evolution as a continuous story, a more abbreviated approach will serve the limited purposes of this excursion quite suitably. The first 150 million years of this story, up until about 35 million years ago, consist primarily of the addition of a succession of “accreted terranes” and an attendant succession of volcanic chains (continental arc complexes) which have developed across them. In this story, there are fundamentally four “terrane belts” which have been added, and four major volcanic arc chains which have developed here. Many of these terrane belts and volcanic chains overlap in the modern North Cascades region. Accordingly, it has been called the geologic “crossroads” of the Pacific Northwest.

The last volcanic (magmatic) arc to develop here was the modern Cascade Arc, which commenced about 35 million years ago, after the four “terrane belts” had been added. Over most of the last 35 million years, these volcanoes erupted on a lowland coastal landscape, accumulating only a modest divide where the modern Cascade Range now stands. That modern range started to rise 5 - 10 million years ago, in a process which continues to date. The outlines of the modern range were eroded by rivers over the first three million years, then shaped by the forces of glacial erosion over the last 2.5 million years. The modern volcanoes like Mt. Baker and Glacier Peak are the most recent in a long line of such volcanoes stretching back 35 million years. These modern peaks are less than 100,000 years old, and largely much younger.
Figure 14 (Above) Generalized map showing the accreted terranes of the Pacific Northwest.
THE ACCRETED TERRANES OF THE PACIFIC NORTHWEST

The “basement” rocks of the Pacific Northwest consist of a succession of “accreted terranes” which have been added to the continental margin over the last 180 million years, extending it westward by some 500 km. Formerly, that coastline lay not far west of modern-day Spokane. These “terranes” included volcanic island groups which had formed in the eastern Pacific Basin, along with scraps of ocean-floor rocks accumulated in various settings.

The first of these “terranes” to be added was a large volcanic-island chain known as the Intermontane Belt. These islands were brought to the shore by the combined westward motion of the continent, and the eastward motion of the underlying oceanic plate. They collided with the continent about 170 million years ago, in Mid-Jurassic time, and now make up a major portion of Western Canada. The second “terrane” was another island-belt of similar character, known as the Insular Belt. This collection of volcanic islands was added to the continental margin in mid-Cretaceous time, about 120 million years ago. It now makes up much of the western coastline of British Columbia.

The last two “accreted terranes” are of much more local extent. The “Melange Belt” terranes which make up the western Cascade foothills and east slope in the Cle Elum area were thrust across the continent in Late Cretaceous time, perhaps 90 million years ago. West of modern-day Puget Sound, the rocks of the Olympic Coast Belt developed on a piece of oceanic crust which was added to the continent by 55 million years ago, in Early Eocene time. Now the “leading edge” of the continent, oceanic rocks have continued to accumulate along this margin. These rocks do not occur in the North Cascades region.

THE INTERMONTANE BELT AND THE METHOW COAST

The first of these “terranes” to be added was a chain of volcanic islands which landed on the continental margin in Mid-Jurassic time, about 170 million years ago. Known as the “Intermontane Belt”, it extends from Kettle Falls on the Columbia River west into the Methow Valley, along the east side of the North Cascades. After this terrane was added to the continental margin, the region now occupied by the Methow Valley became the new western shoreline. Along this shoreline, sediments shed from the continent to the east accumulated in the shallow waters. These sediments eventually became the sedimentary rocks which make up the modern Methow region today. These rocks preserve abundant fossil and structural evidence for a setting along the western shoreline of North America, prior to the addition of the Insular Belt.

*Figure 15 (Right)* Map illustrating the location of the Intermontane Belt, a collection of Pacific island groups which were accreted to the continent around 170 million years ago, in Mid-Jurassic time. These rocks make up the Okanogan Highlands region of Washington State, from Kettle Falls west to the Methow Valley.
Figure 16 (Above)  
Map illustrating the position of the Methow region with respect to the larger Intermontane Belt. From ~170 to ~120 million years ago, this was the western margin of North America. To the north, rocks of the Methow Group as known as the Tyaughton Group.

Figure 17 (Below)  
Ripple marks in the rocks of the Slate Peak Member. These are symmetrical ripples with a wavelength of about 10 cm. These are the right shape and scale to be from the western coast of the continent, some 130 million years ago. This block is from an outcrop at about 5,000 feet in elevation. Elsewhere, rocks from this unit contain abundant fossils of snails, clams, and other shallow-water marine denizens.

Figure 18 (Above) Rocks of the Winthrop Sandstone. These non-marine rocks accumulated during the early phases of the accretion of the Insular Belt. These are the oldest non-marine rocks in the Methow sequence. The dark material at the base of this outcrop is coal, accumulated from organic debris in swampy and boggy settings, here along what was then the coastal margin. Fossils from this assemblage are largely non-marine varieties, and are typically not well preserved.
**The Insular Belt**

The second of these “terranes” was another chain of volcanic islands which landed on the continental margin in mid-Cretaceous time, about 120 million years ago. In the North Cascades, these rocks extend from the Methow Valley west to the San Juan Islands. While it is a more complex assemblage to the north in British Columbia, the representative rocks in the North Cascades are limited to three units. The oldest of these is the Chilliwack Terrane, an old volcanic island group dating from Early Paleozoic (>450 Ma) time. It is a typical volcanic-island package, consisting of mafic to intermediate volcanic rocks, volcanically-derived sedimentary rocks, and sections of limestone. These rocks occur west of Marblemount, where they are the “basement” rocks of the Skagit region. East of Marblemount, Insular-Belt rocks are largely represented by dismembered sections of oceanic rock. These are the remains of the former Bridge River Basin, which intervened between the Insular Belt and the continental margin. In the Skagit region, these rocks are known as the “Napeequa” group. Within the rocks of the Napeequa group are preserved the remains of another volcanic island group, known locally as the Cascade River Group. These rocks include intermediate plutonic bodies (the Marblemount and Dumbell Mountain Plutons) and associated sediments derived from them (the Cascade River and Holden Units). They are of Late Triassic age (~220 Ma), and are part of a terrane known in British Columbia as the Cadwallader Group.

**Figure 19** (Above) Map showing the location of the Insular Belt rocks in Washington. The younger Columbia River Basalts cover the southern end of the region.

**Figure 20** (Right) Typical rocks of the Chilliwack Terrane, the southernmost terrane in the Insular Belt, and the only one exposed in Washington. These are the remains of a volcanic island group, dating from perhaps as early as 450 million years ago.
The Melange Belt Terranes

Unlike the Intermontane and Insular Belts, the Melange Belt Terranes were not of islandic origins. Instead, these rocks appear to represent the remains of a subduction zone, exhumed from a former position along the continental margin. In the Skagit region, these rocks consist largely of sections of oceanic crust and ocean-floor sediments, metamorphosed under the unique conditions found in subduction settings. These rocks are known as the Shuksan Suite, and they occur west of Marblemount, as well as east of Snoqualmie Pass. To the south, most of the rocks of the Melange Belts are a less-recognizable mix of broadly oceanic rocks, the kind of assemblage which accumulates as an “accretionary wedge” above a subduction zone. Collectively, all of these rocks appear to represent portions of a subduction zone, from deep mantle rocks through subducting oceanic crust, through the overlying accretionary wedge.

These rocks were probably not accumulated here. Instead, it seems most likely that they accumulated along the coast of what is now southern Oregon or northern California. With a change in ocean-plate dynamics, it appears that this section of the coast was rifted off the continental margin, and transported northward to this region. When it arrived here, these rocks were thrust northward over the edge of the continent, in a process known as obduction. Moving as great thrust sheets along low-angle thrust faults, these rocks were driven northward by hundreds of kilometers, northward over the southern end of the accreted Insular Belt (here, the Chilliwack Terrane). This appears to have happened about 90 million years ago.

Figure 21 (Right)

Map illustrating the regional extent of the Melange Belts. The area in blue is the Chilliwack Terrane, the southernmost terrane of the Insular Belt. Most of these rocks are discontinuous fragments of oceanic units, but those in the northern end include extensive sections of (now metamorphosed) oceanic crust and ocean-floor mudstones.

Note how these rocks also occur in the Cle Elum area to the east of Snoqualmie Pass. These rocks were thrust over the southern end of the province, which was at the latitude of modern-day Seattle. Later (~50-40 Ma) movement on the Fraser Fault moved rocks on the west side north by about 90 miles (145km).
Figure 22 (Above)

Typical rocks of the Melange Belt in the Skagit Region. The rock on the left is greenschist, the metamorphic equivalent of ocean-floor basalt. The black rock on the (far) right is phyllite, the metamorphic equivalent of ocean-floor mud. Extensive sections of these rocks mark the Skagit region.

Figure 23 (Right)

Map illustrating the inferred history of the Melange Belt Rocks. These rocks appear to have been rifted off a former subduction zone in what is now southern Oregon or northern California. The rocks were transported northward on the oceanic plate and were thrust across the top of the continental margin (obducted) when they
The Olympic Coast Belt

The Olympic Coast Belt is not represented in the North Cascades, although it occupies its western border. The rocks of this belt lie west of Puget Sound, along a fault which presumably floors that feature. The distinguishing character of this unit is an anomalously-thick (15 km) accumulation of ocean-floor basalt (the Crescent Basalts) on a section of oceanic crust. These rocks were thrust beneath the southern end of Vancouver Island (the Insular Belt) by ~55 Ma, in Early Eocene time.

CONTINENTAL ARCS (VOLCANIC CHAINS) AND ANCIENT MOUNTAIN RANGES OF THE PACIFIC NORTHWEST

THE OMEMICA ARC

With the collision of the Intermontane Belt Islands, a modest mountain range was raised along the continental margin. As the oceanic plate was subducted beneath this newly-accreted terrane, a chain of volcanoes (magmatic arc) developed along the mountains of the continental margin between 160 and 140 million years ago. Known as the Omenica Arc, it didn’t extend as far west as the modern Methow Valley of the North Cascades. The sediments which accumulated along that ancient shoreline however, clearly evidence this feature. Early sediments in the Methow sequence reflect active volcanism to the east. Later sediments reflect erosion into the plutonic “roots” of that arc.

THE (CANADIAN) COAST RANGE ARC

While the collision of the Intermontane Belt Islands raised only a modest range of mountains, the accretion of the Insular Belt Islands in mid-Cretaceous time was a much more dramatic affair. It raised a major mountain range extending the length of the Canadian Cordillera and eastward as far as the Rocky Mountain Belt. In this process, the rocks of the accreted Insular Belt were faulted and stacked together, accumulating into a thick “welt” along the continental margin.

As the Insular Belt was accreted, subduction of the outboard oceanic crust beneath this newly-accreted margin gave rise to a new magmatic arc (volcanic chain), known as the (Canadian) Coast Range Arc. This episode of magmatism was initiated about 100 million years ago, and persisted to about 60 million years ago. In a regime which ultimately spread the length of the North American coast from Alaska to Baja California, this was the largest magmatic-arc complex to ever develop on the North American continent.

Over the course of the Coast Range episode, huge quanti-

Figure 24 Right)
Map showing distribution of granite-type rocks intruded during the Coast Range Episode of regional magmatism. Most of these rocks range in age from 100 to 60 million years ago. In the North Cascades, these are the dominant rocks of the upper Skagit region.
Figure 25 (Above)
The ancestral Canadian Coastal Range, ~75 million years ago. This was likely a Himalayan-scale feature, judging from the amount of crustal shortening. Deep beneath these mountains, large amounts of granitic rocks were intruded (see figure 24, left). A range of this scale may have persisted from ~100 to ~60 million years ago, and was at times a continental-scale feature extending south into California.

Figure 26 (Right)
Steeply-stacked sections of old oceanic crust, collapsed in the accretion of the Insular Belt. This process accumulated a substantial mountain-range at the time.

Marble Creek divide, southern Skagit region.
ties of granitic magma were intruded into the North Cascades region. Early in the episode, magmatism was concentrated to the southwest, migrating to the northeast over time. In the Skagit region, most of the intrusion dates from 75 to 60 million years ago. Repeated intrusions served to bury older rocks, and added greatly to the thickness of the crust here. In this process a very impressive range of mountains was likely raised, a Himalayan-scale feature along the continental margin. At depth, the intruded granitic material accumulated to form over 80% of the rocks here, most of it metamorphosed to gneiss. The resulting rocks are known as the Skagit Gneiss Complex.

The Coast Range episode drew to a close around 60 Ma, as changes in regional plate-tectonics no longer supported the Coast Range Arc. This is the age of the youngest Coast Range rocks.

**Figures 27, 28** (Above) Typical rocks of the Skagit region. Rocks on the left are highly-metamorphosed volcanic-island rocks. Along with equivalent ocean-floor rocks, they comprise 20% of the Skagit rock. Most of the rock in the Skagit region is typical of that on the right. These are gneiss, highly metamorphosed plutonic (granite-type) rocks. These rocks were intruded and metamorphosed during the Coast Range episode.

**Figure 29** (Right) Map showing the distribution of plutonic (granite-type) rocks in the North Cascades. Rocks in pink were intruded and metamorphosed (light pink) between 100 and 80 million years ago. Rocks in yellow were intruded and metamorphosed (light yellow) between 80 and 60 million years ago.
The Challis Episode and the Fraser Fault

The “Challis” Episode of the Eocene Period is unquestionably the most enigmatic episode in the course of regional geologic history. We suspect that this episode records a major transition in ocean-plate tectonics, an aspect beyond our summary treatment here. For our purposes, this episode is known for a regime of (arc?) magmatism across the eastern half of the North Cascades, the accumulation of thick regional sequences of sedimentary rock, and for a succession of deformational events reflected in the modern geology of the region. All of these events took place between 57 and 36 million years ago.

Challis magmatism includes a suite of plutons in the North Cascades, extending east across Northern Washington into central Idaho (Challis, Idaho). These plutons are the roots of volcanoes which developed over this period. In the Skagit region, an extensive set of granitic dikes (veins, cross-cutting the older rocks) date from this episode.

Figure 30 (Right)

Regional paleogeography during the Eocene Challis episode of 57 - 37 million years ago. Over this period, much of Washington was a lowland coastal floodplain province, home to a large river system draining from the northeast. Fossils from this episode reflect a paratropical setting, the dominant species being palm trees.

Figure 31 (Right)

Rocks of the Golden Horn Batholith, north of Washington Pass. These are typical granitic rocks of the Challis Episode. They can often be discerned by their distinctive pink color. They are some of the few true granites (as opposed to granodiorites) in Washington.
On a regional scale, the most wide-spread development of this episode was the accumulation of thick sequences of river-laid sediments across much of modern-day Washington State. These were deposited by a major river system draining across a broad coastal floodplain here. Although not preserved well in the Skagit Valley, these are some of the thickest non-marine sedimentary formations in North America. Local examples include the Chuckanut Formation around Bellingham, and the Swauk and Roslyn Formations east of Snoqualmie Pass. Fossil assemblages in these rocks reflect a warm, moist, paratropical setting at the time. These rocks date from 53 - 40 Ma.

From a map perspective, the most graphic development of this Challis episode was the deformational regime which accompanied faulting on the Fraser Fault System. As part of this regime, the rocks of this region were folded along NW-SE trending folds, a structural pattern which still dominates the regional setting. This pattern of folding was responsible for establishing the broadly antiformal (fold crest) structure of the North Cascades region.

On a larger scale, this deformational regime ultimately resulted in the formation of the Fraser Fault, a 5000-km-long north-south trending transform fault, along which the west side has been displaced to the north (here) by about 150 km (90 miles). This major fault offsets all older terrane belts, as well as recent accumulations such as the Swauk and Chuckanut Formations, which were formerly coextensive. Of equal significance, it juxtaposes shallow rocks on the southern end of the region (e.g. the Melange Belts) against much deeper rocks (e.g. the Skagit Gneiss) to the north.

**The Modern Cascade Arc**

The plate-tectonic transition of the Challis episode ended as the Juan De Fuca (Farallon) Plate began subducting beneath the modern continental margin about 37 million years ago. Since that time, Cascade Volcanoes have been

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**Figure 32 (Right)**

Map showing displacement on the (Eocene) Fraser Fault, between 50 and 40 million years ago. Rocks on the west side of the fault were displaced to the north by about 90 miles (145 km). This fault offsets all older rock units.

In this same episode, the rocks of the Olympic Coast Belt were added to the continental margin, thrust beneath the southern end of Vancouver Island.
growing along the coast here. Over most of that period these volcanoes erupted on a lowland coastal floodplain, along a shoreline which extended along modern-day Interstate 5. The rise of the modern Cascade and Olympic Mountains, and the emergence of the Olympic Peninsula, are much more recent events. Over most of this period, the “Cascade Crest” was a localized accumulation of volcanic rocks less than a kilometer in elevation. Based on maritime conditions reflected in the fossil record to the east, they did not present an orographic barrier to Pacific storms.

Volcanoes are transient features on the landscape, rarely persisting for more than a few hundred thousand years. There have been a long succession of Cascade-arc volcanoes in the North Cascades, all which were consumed by the forces of weathering and erosion. What has endured are the deep plutonic (granite-type) “roots” of those volcanoes, exposed by the recent uplift of the modern range. These granite-type rocks were intruded at depths of ~3 km, and accumulated by repeated episodes of intrusion. The largest accumulation of these rocks is the Chilliwack Batholith (an exposure exceeding 100 km square) to the north of the Skagit River. These deeper crystalline rocks accumulated from a succession of volcanoes which grew here from 36 to 7 million years ago.

Between 5 and 7 million years ago, the locus of the Cascade Arc shifted west, out of the Chilliwack region and into the Mt. Baker Region. Since that time, volcanoes have been growing in the Mt. Baker area. The oldest of these dates from about 4 million years ago, while the modern cone of Mt. Baker has accumulated only over the last ~50,000 years. It is only the most recent in a succession of volcanoes rising in this locale.

**Figure 33 (Right)**

Map showing the setting of the modern Cascade Episode. This arrangement has been in force for the last 37 million years.

Here, the Juan De Fuca Plate, produced along the Juan De Fuca Ridge, is expanding to the east. As it meets the (westward moving) continent, it is forced beneath the continental margin (subduction). At depth, this causes melting of rocks which rise through the crust to erupt as the Cascade Volcanoes. At depth, this process intrudes large amounts of granite-type rocks.

The modern volcanoes noted here are only the most recent members of a long lineage of such peaks. The two volcanoes of the North Cascades (yellow area) are Mt. Baker and Glacier Peak.
The Modern Cascade Range

The modern Cascade Range is a recent feature developed over the last ten million years. The North Cascades has a somewhat longer uplift history, starting somewhere around 10 million years ago, as the southern end of the Canadian Coastal Range. Most of the Cascade Range started rising about 5 million years ago. Along with the Olympic Mountains to the west, they are an antiform (fold crest) structure, with the Puget Basin lying as the syncline (fold trough) between them. This started about 5 million years ago, when a change in plate geometries started compressing the edge of the continent here. As these rocks were uplifted, erosion began to cut the initial features of the mountain landscape. Since that time, up to 2 km of material have been eroded, much of it originally by stream erosion. The basic features of the landscape were established prior to the onset of the glacial episodes, which further sculpted the region to its modern alpine form.

Figure 34 (Right)

Area of the (northern) North Cascades showing the relationship between the (36-10 MA) Chilliwack Batholith and modern-day Mount Baker to the west. The Chilliwack Batholith consists of granite-type rocks accumulated from many different volcanoes which grew in this area over this 26 million-year span. These rocks were intruded at depths of about 3 km, which is the amount of uplift experienced in the rise of the modern Cascade Range. With that uplift, these rocks have been exposed.

Starting 5-7 million years ago, the location of the Cascade Arc shifted to the west, into the modern Mt. Baker region. Over the course of the uplift of the modern range, volcanoes have been growing in this area. Mt. Baker is only the most recent in that long lineage of volcanic peaks.
Mt. Baker, a modern Cascade-Arc volcano. The view here is from Austin Pass at the Mt. Baker Ski area, looking to the west.

The modern cone of Mt. Baker has probably been accumulating for something like 50,000 years, but much of the modern edifice is probably much younger.

Diagram illustrating the rise of the modern Cascade and Olympic Mountains. These ranges resulted from east-west compression, a product of steepening ocean-plate subduction and the continued westward movement of the continent. The eastern of the folds was eroded to form the Cascades, the western of the folds was eroded to form the Olympics. The Puget Basin the the structural trough between these two folds.
Glaciation of the Modern North Cascades

The North Cascades are the most heavily-glaciated range in the United States, south of Alaska. While its modern glaciers are restricted to the high summits, the form of these mountains reflects multiple episodes of both continental and alpine glaciation, in a history stretching back some two million years. While the mountain range was a well-established feature by the dawn of the ice ages, these glacial episodes were responsible for sculpting that original landscape into a distinctly glacial setting.

The North Cascades Mountains display the classic forms of a glacial landscape. The faces of its mountains have been sculpted by ice into bowl-shaped cirques, its ridges have been sharpened into steep arêtes, and its summits have been honed to sharp horns. The ice which carved these high mountain features flowed down the slopes into the valleys, which it shaped into deep, steep-sided troughs. Compared to river – cut valleys, which have a characteristic “V” shaped profile, these glacial troughs have a distinctive “U” shape to them. These deep troughs joined together in the main valleys, carrying ice down out of the mountains and onto the lowlands below.

We don’t know how many episodes of alpine (local) glaciation this region experienced, but it was certainly dozens. In some of those episodes, ice flowed out of the mountains and onto the surrounding lowlands. In other episodes, it only filled the high cirques and valleys of the range. In each case, it was responsible for modifying the landscape into its modern glacially-eroded form. The most recent major episode of alpine glaciation was from 25 – 18,000 years ago, known as the “Evans Creek” episode.
In addition to local episodes of alpine glaciation, the North Cascades was repeatedly over-run by the continental-scale icecaps which developed to the north. In those events, of which there were probably dozens, ice advanced south out of what is now Canada, advancing down the Puget Basin and the upper Skagit Valley. Ice advancing down the Puget Basin flowed up the Skagit River for some distance, while ice flowing south down the Baker River Valley also reached the Skagit. To the east, ice flowed down the upper Skagit continued south up the Granite Creek drainage, flowing over the crest and down into the Stehekin and Methow Valleys. At its maximum extent during the last ice-age, continental ice mantled the North Cascades over almost the Skagit drainage.

**Figure 38** (Right)
Le Conte Peak, north of Glacier Peak. Note the massive cirques on this side of the peak. The upper cirque still holds glaciers, while the lower cirque now holds a small lake.

Arrows point to well-defined aretes, sharpened on both sides by glacial erosion. Photo by R. Tabor, USGS.

**Figure 39** (Right)
The Methow Valley, showing the classic “U”-shaped profile typical of glacial troughs. This is a spectacular example of this landform.

All of the valleys of the North Cascades started out as river-cut features. These were later modified by glacial processes.
The most profound effects of continental glaciation have been on drainage patterns in the Skagit region. Originally, many of the rivers in the upper Skagit region (including the upper Skagit itself) drained to the north. As ice advanced south up these valleys, lakes accumulated in advance of the ice. In many cases those lakes grew to overtop the ridges at the head of the drainages, and cut new routes to the south. When the ice retreated, many of these river drainages had reversed their course, from north to south. The upper Skagit is an example of this, originally draining north from a head near modern-day Diablo. Ice advancing from the north accumulated a lake in the upper Skagit, which overtopped the divide and cut the spectacular Skagit Gorge to drain to the lower Skagit below. Over the early glacial episodes, the course of the upper Skagit was reversed from north to south, and it became the head of the modern Skagit system.

Just as the ice of the continental icecaps reversed the course of rivers, it also developed new river channels as it diverted their courses. A good example of this occurred as the Puget Lobe Glacier decended the Puget Basin, damming rivers like the Nooksack and Skagit to the east. Large lakes formed in these valleys, eventually cutting routes through the intervening ridges in order to drain to the south. The impounded waters of the Nooksack River cut the Wickersham Spillway through the divide, to drain to the Skagit at modern-day Sedro Woolley. As the Skagit was dammed by the advancing ice, its impounded waters eventually overtopped a divide south of Rockport, cutting the Sauk River Valley south to the Stilliguamish River.

Figure 40 (Above)
Image showing some of the classic glacial features displayed on these mountains. Illustrated here are a succession of three glacial cirques, the lowest of which has been abandoned. Also pictured are a glacial horn (Klawatti Peak) and a number of prominent aretes.
The Post-Glacial North Cascades

Continental ice had largely vacated this region by 12,000 years ago, ushering in the modern interglacial period. Since that date, the alpine glaciers in the range have waxed and waned with the evolving climate. They were probably at a minium during the Medieval Warm Period from 950 - 1250 CE, and at a maximum during the “little ice age” of 1500 to 1850 CE. The modern glaciers were relatively stable through the 1950’s, but most were in decline in the years that followed. At current rates, most will be gone within 50 years, and virtually all will disappear within a century.

The region evolved from a post-glacial setting to a range of temperate rainforest species over several thousand years. The first native peoples to this region appeared some 9000 years ago, to a setting in this process of transformation. Over the generations, they witnessed the development of the mature old-growth temperate rainforest which used to carpet this region.

Non-native settlement of this region dates from an early horizon of about 1850. Within a hundred years, the mature old-growth temperate rainforest had largely disappeared from the landscape. It should be emphasized that the lower portions of the Skagit drainage bear scant resemblance to the natural conditions which persisted until just a few generations ago.

Figure 41 (Above)
Forbidden Peak, a classic glacially-carved massif in the North Cascades. This peak illustrates the major glacial features, including horns, aretes, cirques and a deep glacial trough.
Introduction:

This version of the Skagit River Trip ascends SR 20 as far as the Ross Lake Overlook, and includes eight field stops en route. This is about the most which can be done in a day from the Seattle area. While mileage figures are not given in this version, the stops are described and illustrated in enough detail that they are easily located. Except for stop 7, all stops can be reached year-round.

It is worth remembering that marine moisture frequently ends at about Newhalem, and the upper Skagit often enjoys better weather than the west side. Newhalem is the typical lunch stop, with public restrooms, a small store, interpretive centers and a nice park area with picnic tables.

Figure 42  (Above) Map of the Skagit River region, showing the field trip route
Figure 43  (Middle Right) Fields of daffodils, Skagit Valley
Figure 44  (Top Right) View of Mt. Baker, from the Skagit Flats on Interstate 5
Figure 45  (Bottom Right) Sedro Woolley, sign at town entrance.
Mount Baker View
Approaching Mt. Vernon across the Skagit Floodplain (the “Skagit Flats”), Mt. Baker comes into view briefly, through a gap in the ridge to the east. It is a truly picturesque vantage on the mountain, with a pastoral setting in the foreground.

Mount Vernon
The city of Mount Vernon dates from 1877, and in its early years was overshadowed by the older settlements of Utsalady and LaConner to the west. The city grew as the headquarters for agriculture on the bountiful Skagit Flats, and also served the timber industry for many years. The “city of the soft petal”, it is now the west coast center for the American Bulb industry. In season, vast fields of flowers carpet the Skagit flats, shipped worldwide as fresh flowers and seed bulbs. The popular Skagit Valley Tulip Festival showcases the industry each spring.

Intersection with the Cook Road (Exit 232)
Take the Cook Road exit and head east. This is the route that the locals use. It avoids the towns of Burlington and Mount Vernon.

Heading east on the Cook Road, you notice a number of prominent knobs which mark the floor of the valley, including a major hill north of the town of Burlington.

Sedro Woolley
The original town of Sedro (from cedro, Spanish for cedar) was settled by Joseph Hart and David Batey in 1878. In 1890 Phillip Woolley platted a rival town (Woolley) on the other side of the river. After years of competition, the two towns merged in December of 1898. Unable to settle on a new name, they adopted this somewhat awkward combination of the two. Historically, the town has largely been supported by agricultural and timber
industries. During World War II, a large manufacturing plant was built here by Bendix. It now serves as the city industrial park. The town has a population of about 9000 people, and bills itself as the “gateway to the North Cascades”.

Much of the valley floor around Sedro Woolley, and as far east as Lyman, is covered in lahar (volcanic mudflow) deposits. These were discharged from Mt. Baker, and from Glacier Peak to the south.

**Wiseman Creek, Pleistocene gravels**

Quaternary sediments are exposed in the road-cut and gravel-pit here. The lower portions consist of foreset beds of sand and gravel, likely accumulated as an ice-marginal lake in the Skagit Valley drained with the retreat of the continental icecap. Note that these deposits pre-date the latest glacial episode, as they are covered in recent glacial till.

**Baccus Road (Chuckanut Formation)**

The first hundred yards up the Baccus Creek Road is in non-marine sedimentary rocks of the Chuckanut Formation, a sandstone cover of Eocene origins. These rocks are 50 - 55 million years in age. While this unit accumulated to over 5 km in thickness, it has largely been eroded off the Skagit drainage. Only meager exposures like this remain. It is much better preserved to the north, in the Nooksack drainage.
The Chuckanut Formation is the western counterpart to the Swauk Formation east of Snoqualmie Pass. These were deposited before displacement on the Fraser Fault, and are now offset by 145 km (90 miles). These rocks reflect a lowland coastal floodplain setting, featuring a paratropical climate in a landscape dominated by palm trees and similar broad-leaf vegetation. The formation is locally fossiliferous, but rock is hard to find in the heavily-vegetated setting here.

**Lyman**

Lyman and Hamilton were founded to support timber camps on the upper South Fork of the Nooksack River. Hamilton is perennially flooded by the Skagit, and is presently moving its location.

**Concrete**

Local speed trap  
Food, gas, citations

Situated at the mouth of the Baker River, Concrete was once known by the more poetic name of Baker. It was platted by Magnus Miller in 1890, and a road reached this point by 1900. The Washington Portland Cement Company was established here in 1905, and the town adopted its present name in 1909. One of its earliest contracts was to provide concrete for the new Lake Washington Ship Canal in Seattle. It was a major supplier of concrete for building the dams on the Skagit and Columbia Rivers, before the limestone deposits played out in the late 1960’s. For decades, this part of the valley was perpetually mantled in a gray coat of limestone dust. In 1921, several fires destroyed much of the downtown business district. Formerly a larger town, it now has a population of about 800.

The town suffered some measure of national embarrassment in 1938, as H.G. Wells made his famous radio broadcast of the “War of the Worlds.” During this broadcast a powerful storm caused a power outage in Concrete, which led people to believe that the Martians had captured Baker Dam. Armed citizens took to the streets with the intent of battling the invading extraterrestrials, until power was restored and the nature of the broadcast was revealed. The incident made the national press, with much local embarrassment.

The town now makes much of its income by rigorously enforcing the 35 mph speed limit along this portion of the state highway. Local law enforcement patrols this stretch on a full-time basis.

Just past the Baker River Bridge, turn left on Everett Avenue. Continue for several blocks to E. Main Street and turn left. East Main Street continues past the concrete works, and past the junction with the Dillard Avenue Bridge (on the left) to Baker Dam.

The Dillard Avenue (Henry Thompson) Bridge was built in 1916-18. In its time, it was the longest concrete single-span bridge in the world.

**Baker Dam**

Baker Dam impounds the waters of Lake Shannon, part of a hydroelectric project owned by Puget Power. The dam was built in 1919, and at the time was the tallest concrete arch dam in the world – a title it held until the construction...
of Hoover Dam. The structure has ridden out numerous earthquakes, landslides and other events, and is now nearly 100 years old. It was recently re-licensed for the next 50 years.

From here the road continues as the Baker River Road. Take the lower road at the first intersection past the dam. Take the upper road at the second intersection. The road is often gated, just below the entrance to the quarry.

Stop 1 Concrete Quarry

This quarry was the source for the limestone which was used to make Portland Cement, the essential ingredient in concrete. The quarry is in a pod-like body of limestone, which finally played out in the late 1960’s. When this happened, the concrete-making era in this area ended.

The limestone unit here is part of the Chilliwack Group, the remains of an island-arc complex which eventually became amalgamated as part of the Insular Belt. This particular section is part of the Mississippian Red Mountain Subgroup, which contains extensive limestone beds (particularly, north of the Nooksack River). These are biogenic limestones, the remains of reef-type colonies which developed in the waters around the ancient Chilliwack Islands in Late Paleozoic times. Those colonies consisted largely of crinoids (aka “Sea Lillies”), which are abundantly preserved in fossil form here. What are most typically seen is the “bulls-eye” pattern which is the cross-section of the stalk of the organism.

These rocks have been very mildly recrystallized at sub-greenschist levels of metamorphism. Compared to the volcanic rocks of this suite, the limestone units tend to be relatively undeformed, preserving a good fossil record of that time.
From the quarry, one gets a nice view of Mt. Baker on a clear day. Mt. Baker is a Quaternary stratovolcano of andesitic composition. It is largely younger than 50,000 years in age, and last erupted in 1870. Pound-for-pound, it is the most heavily glaciated volcano in the range. A major danger is from lahars flowing down this side of the peak, into the lakes impounded by the dams here.

Also in view here is the 9117’ peak of Mt. Shuksan, directly to the north. This peak is comprised of greenschist and phyllite of the Shuksan Suite.

Return to Highway 20 and continue east.
Just outside of town the road cuts through thick sections of glacial till adjacent to the river. These deposits are discussed below.

**Sauk Mtn View**

Sauk Mountain (5537’ 1618m) rises from the valley to the north here. This peak is comprised of rocks of the Chilliwack Terrane. The lower portions are largely (meta) volcanic rock, but near the top they transition to (meta) sedimentary rocks through a breccia facies.

Sauk Mountain is one of the more popular short hikes in Western Washington. A road reaches high on the south side of the mountain, and the ascent is largely through meadowed slopes. An old fire-lookout is maintained on the summit. On a summer weekend, hundreds of people hike this trail. It features an outstanding view of Mount Baker, to the west.

**Rockport State Park**

Rockport State Park is 670 acres of pristine old-growth forest given to the state by the Sound Timber Company in 1935. It was developed as a park in the 1960s.

The park sits atop a large moraine deposit. This represents the terminal moraine of the continental ice lobe that advanced up the Skagit Valley about 17,000 years ago. Similar advances up the valley accompanied the earlier episodes of continental glaciation. That ice served to dam the Skagit River, forming a large lake in the valley here. The waters of that lake rose until they overtopped a divide to the south between the Skagit and Stillaguamish Rivers. Water draining from the lake cut a deep channel through the mountains to drain south to the Stillaguamish Valley. This is the source of the deep north-south trending valley between Rockport and Darrington, a valley which iso-

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**Figure 52** (Left) Sauk Mountain, from the Skagit Valley. This is a popular summer hike, rising through the meadows visible on the slopes here. A fire lookout marks the summit.

This peak is made up of rocks of the Chilliwack Terrane, the remains of a volcanic island which developed over the Paleozoic. Most of the rocks on the mountain are volcanic varieties, but sedimentary rocks cap the upper ridge-crest.

**Figure 53** (Right) An old log cabin, in the town of Rockport. Photo by Jesperado.
lates a sub-range of mountains to the west. It is occupied by the Sauk River, which is vastly undersized for the scale of the valley.

**Rockport**

Rockport was first platted in 1901, by Skagit pioneer Albert Von Pressentin. For many years it was the end of the rail line, which extended west from Anacortes. The town hosts the annual Skagit River Bald Eagle Festival in late January or early February. About 400 eagles typically winter on this stretch of the Skagit, feeding on the winter salmon runs.

**Stop 2  Melange Belt Rocks**

There are two rock types on display here, including a greenschist (Shuksan Greenschist) and a phyllite (Darrington Phyllite). These are rocks of the Shuksan Suite, part of the Melange Belts of terranes which were thrust northward over the Chilliwack Terrane in mid-Cretaceous time. The greenschist is a meta-basalt of ocean-floor origins, while the phyllite is derived from the ocean-floor mud which accumulated upon it. They are part of a larger assemblage which includes ultramafic rocks (the Twin Sisters Dunite) and various mélange units. The Shuksan rocks, while not particularly evident here, are locally metamorphosed at blueschist facies, the signature of subduction-zone conditions.

Given the general character of rocks in this package, it appears that these were the components a coastal subduction zone which was tectonically exhumed from a southern locale in Early Cretaceous time. These rocks were transported northward on an oceanic plate, and were subsequently obducted (thrust over) the southern margin of the accreted Insular Belt. Here, that southern margin consisted of the Chilliwack Terrane.

The Shuksan rocks overlie the Chilliwack Terrane along a low-angle thrust fault known as the Shuksan Thrust. In the
San Juan Islands to the west, this same thrust is known as the San Juan Thrust. To the east, its counterpart is the Windy Pass Thrust along the south side of Mt. Stuart, east of Snoqualmie Pass. These rocks overthrust the continent perhaps 90-95 million years ago. In Eocene time, the eastern and western portions were displaced by right-lateral movement on the Fraser Fault. Formerly, they were coextensive.

This stop lies with a former divide between the Skagit and Sauk Rivers. As illustrated on the following page, this divide was eroded away as a proglacial lake in the Skagit Valley overtopped it, flowing south into the Stillaguamish drainage. During the early stages of the various glacial advances, this served in an ice-marginal river system as the waters of the Fraser, Nooksack and Skagit Rivers were diverted to the south.
Figure 56  (Right)

Map of the lower Skagit region, showing the relationship between rocks of the Insular Belt (Purple, here, rocks of the Chilliwack Terrane) and the overlying rocks of the Melange Belts (Green). The low-angle thrust fault between these units is marked in red, with the triangles on the upper-plate rocks. Inset shows map area. Stops 1, 2 and 3 are located.

In contrast to the more mixed character of the Melange Belt rocks to the south, representatives in this area include large sections of oceanic crust (now, greenschist) and ocean-floor sediments (now, phyllite).

The black line along the eastern edge of the map represents the Fraser Fault, which separates shallower elements of the region on the west from deeper elements to the east. There is about 90 miles (145km) of west-side-north displacement on this feature.

Figure 57  (Left)

Map diagram illustrating the suspected origins of the Melange Belt rocks. These appear to be components of a former subduction zone along the southern Oregon or northern California Coast. Elements of this assemblage were rifted off the coastal margin, transported northward, and were thrust over the top of the continent (here, the Chilliwack Terrane) about 90-95 million years ago.
This river-side park is a popular venue for eagle-watching during the winter, and the site of the annual Bald Eagle Festival in January or February. About 400 eagles typically winter on the Skagit here, feeding on the salmon runs.

Figure 58  (Left)  
Three images illustrating the evolution of the Sauk River Valley over the early glacial episodes. Base images from Google Earth.

Top image shows the area before glaciation, as an ancestral Sauk River rose on a crest between the Skagit and the Stillaguamish, to the south.

Middle image shows the Skagit Valley flooded by continental ice to the west, advancing up the valley from the Puget Basin. White arrow shows where flood waters overtopped the crest of the former ridge here.

Bottom image shows the modern landscape, with the Sauk River breaching the former divide through a valley carved by glacial floodwaters.

Figure 59  (Below)  Bald Eagles winter on the Skagit in the Rockport area. Photo from the National Audubon Society.
Marblemount  Elevation 327’

Grocery, automotive services, Restrooms
National Park Service District Headquarters

Watch for pedestrian traffic

Marblemount is the highest (public) settlement on the Skagit. An important center in the various “gold rushes” in this area, in 1890 it hosted a (largely tented) population of some 1500 people. At the time, it was billed as the “coming Leadville of the Pacific”. The silver crash of 1893 left it a virtual ghost town. The Log Cabin Inn is an original structure dating from 1896. The National Park Service district headquarters is located here, at the end of Ranger Station Road. Public restrooms at the ranger station.

Intersection with the Cascade River Road
Turn left and continue west (here, north) on SR 20

Diobsud Creek (Fraser Fault)

“Diobsud” is a local contortion of the mineral name diopside. Early prospectors found epidote, and misidentified it as such.

Here we are crossing the (Eocene) Fraser (Straight Creek) Fault. This is a north-trending fault which displaces the west side to the north by about 145 km (90 miles) The notches in the hills due north of here reflect the trace of the fault. The Skagit River follows the fault south from here.

Continue to .5 miles past MP 109
Stop 3  Marblemount Meta-Quartz Diorite,  The Fraser Fault

Having crossed the Fraser Fault, we are now in the much deeper rocks of the Skagit “Core” region. Most of the rocks are granite-type varieties dating from the Coast Range episode of mountain-building, between 100 and 60 million years ago. The rocks here are granite-type species, but are considerably older. These are 220-million year old rocks from one of the island groups of the Insular Belt, a section known locally as the Cascade River Group. These rocks extend some 150 km southeast along the southern margin of the Skagit region.

These rocks were mildly metamorphosed during the Coast Range Episode, as evidenced by the greenish tinge to the rocks (original plagioclase feldspar has turned to epidote). What is best evidenced here however, is how these rocks have been deformed by movement along the adjacent Fraser Fault. Walking the length of the outcrop, you can see that sections of the rock have been sheared, where the dark-colored minerals have been drawn into a parallel alignment. These alternate with undeformed sections, illustrating that shearing occurred heterogeneously. These events happened between 50 and 40 million years ago, as the west side was displaced northward by some 145 km.

Figure 61  (Right)

Image showing the location of the Fraser Fault, relative to the town of Marblemount. View is to the north, Mt. Baker in the background.

Movement on this feature between 50 and 40 million years ago moved rocks on the west (left) side northward by about 90 miles (145 km). This juxtaposed shallow rocks from the southern end of the province against deep rocks on the northern end. Base image from Google Earth.

Figure 62  (Right)

The Marblemount Meta-Quartz Diorite, a granitic rock. Sample on the right is undeformed, sample on the left shows the effects of shear, generated along the Fraser Fault. The original granite-type rock is about 220 million years old.
Because the region now occupied by the North Cascades was tilted to the south at the time, this served to bring shallow (Melange Belt) rocks from the south, juxtaposing them against much deeper rocks of the Skagit “core” region to the north. The result is an abrupt transition from low-grade greenschist and phyllite on the west to high-grade schists and gneisses on the east.

This is a continental-scale feature, extending from the Columbia River north into Alaska. Most noticeably, the fault is followed by the Fraser River (British Columbia) for a considerable distance.

Continue east on SR 20

Now entering the Ross Lake National Recreation Area, North Cascades National Park Complex. Under federal law, sample collecting is prohibited except by special permit. Please help preserve our national parks for future generations. Any samples worth taking are worth leaving for others to see.

The North Cascades National Park was established in 1968, over the vocal opposition of the US Forest Service, timber interests and many local communities. The park is a “wilderness park”, while the adjoining recreation areas (Ross Lake, Lake Chelan) are more heavily utilized. This is the most rugged wilderness in the United States, south of Alaska.

**Goodell Creek Campground**

Views to the north (through the trees) are of the rugged Southern Picket Range, deeply sculpted by alpine glaciers. They are largely carved out of the Skagit Gneiss. The last major episode of alpine glaciation here climaxed between 20 and 18,000 years ago, before the last advance of the continental glaciers into the region. This was known as the “Evans Creek” episode of alpine glaciation. These jagged peaks reflect numerous episodes of both alpine and continental glaciation.
Newhalem

Elevation 525’ (160m)
Grocery, public restrooms, interpretive centers

Newhalem is a very neat and tidy company town of Seattle City Light, serving the Skagit hydropower projects. It was originally the site of an Upper Skagit tribal encampment known as “Ne-Wha-lem” – meaning “a place for killing goats” (by driving them over the cliffs). It became a trading post (Goodell’s Landing) in 1880, at the head of canoe navigation. It served the periodic gold rushes on the upper Skagit, despite the difficulty of trail access up the gorge. The modern town was built in the 1920’s. Seattle City Light and the National Park Service both have interpretive centers here. There are no automotive services, although there is a small general store.

The speed limit through town is 35 mph, rigorously enforced by both county and state police.
Stop 4 The Skagit Gneiss

East of the Fraser Fault, the dominant rock in the upper Skagit region is gneiss, a high-grade metamorphic rock. Most of the gneiss in this region is called an orthogneiss, because it is derived from rocks which were originally granite-type varieties. These rocks were intruded as part of the Coast Range Episode of mountain-building, which developed between 100 and 60 million years ago. These granite-type rocks were intruded at considerable depths (here, perhaps 20 km) beneath the large range of mountains which developed over this period. They were produced during a period of rapid plate subduction, which generated the voluminous quantities of magma which intruded into this region.

In this region, most of that granite-type rock was intruded between 80 and 60 million years ago. Rather than intruding as one large mass of magma, the rocks in this area evidence repeated intrusive events, all adding to the pile of rocks accumulated here. In this process, the older granite-type rocks were metamorphosed (recrystallized, under heat and pressure) by subsequent adjacent intrusions. This transformed normally these directionless granite-type rocks into varieties characterized by a parallel orientation of their minerals (most noticeably, the dark-colored varieties). When (as here) those light and dark-colored minerals and segregated into distinct bands, the rock is known as a gneiss. In this area, metamorphism happened at temperatures of perhaps 500°C, and under as much as 5,000 atmospheres (5 kilobars) of pressure.

Something on the order of 80% of the rock in the Skagit region is orthogneiss, a product of the voluminous quantities of magma intruded over the Coast Range Episode. Here, that magma intruded rocks of the Insular Belt, including rocks of the Cascade River (Cadwallader) island Group (as seen at stop 4). Most of the original rocks in this area, however, were oceanic rocks of the Napeequa Group. These rocks are the remnants of the ancestral Bridge River Ocean Basin, which intervened between the Insular Belt Islands and the western margin of the continent. When the Insular Belt was accreted (about 120-110 million years ago), a narrow belt of these ocean-floor rocks was preserved in this region. When metamorphosed under these conditions, these rocks produce varieties which have a well-defined sense of orientation to their minerals, but are more homogeneous than the distinctively banded gneisses. These rocks are known as schists. In the Newhalem area, conditions have produced schists dominated by mica-type and darker (amphibolite) minerals. The various micas are of different colors, and impart an attractive sparkle to the rock. Further east, as the metamorphic grade increases, garnet-bearing schists are found.

*Continue east on SR 20*
Steep, winding mountain road for the next six miles. Use appropriate caution.

Rockslide

A large rockslide crashed down the north canyon wall here in 2003, closing the highway for several weeks. The slide started as a section of weak rock adjacent to a north-trending fault gave way. This fault is probably one of the local north-trending shear faults which developed in response to motion on the (Eocene) Fraser Fault to the west.

Gorge Dam

Completed in 1924, Gorge Dam was the first of the Skagit hydropower projects undertaken by Seattle City Light. The dam itself is a simple impoundment structure. Water from Gorge Lake flows directly into large tunnels on the other side of the dam.
canyon, bored through two miles of solid rock down to the powerhouse in Newhalem. The project was a quite remarkable (and contentious) engineering feat in its day, and the powerhouse reflects the classic architecture of the time. In dry months, there is no river between the dam and the powerhouse.

**The Skagit Gorge**

As described at the next stop, the Skagit Gorge has its origins in the early episodes of continental glaciation, in a process which reversed the flow of the upper Skagit from north to south west. Prior to that time, this was the headwaters of the lower Skagit system. The gorge is a deep canyon eroded out of the bottom of that pre-existing valley. Glacial striations in rocks above illustrate that the valley was occupied by ice at the height of the continental glaciations, with ice flowing down the valley to the west.

Until the City of Seattle blasted a narrow-gauge rail route up the gorge in the 1920’s, this deep canyon presented a formidable obstacle to travel up the Skagit. The river coursed down this gorge in a dramatic succession of cataracts, with the sound reverberating off the steep canyon walls in an absolutely thunderous roar. Even the native tribes did not have a trail climbing this awesome canyon, preferring a route over Cascade and Park Creek Passes to the south.

The “trail” up the gorge was “built” by prospectors and miners, willing to risk life and limb for a chance at wealth. These were not entirely rational people, and they definitely weren’t engineers. The “trail” consisted of a series of precarious goat-paths linked by a collection of bridges and walkways of notoriously dubious character. Some of these structures were literally suspended on cliff faces over the churning waters. It was not a route suitable for pack animals, a fact proven on a regular basis with tragic results. As a consequence, early access to the upper Skagit was largely from Canada. Cascade Pass (20 miles south of here) was the northernmost practical route across the Cascades in Washington.

**Gorge Creek Falls**

Restrooms, tourist hordes, pedestrian hazard

*Watch for Pedestrian Traffic*

Gorge Creek cascades (in season) down a deep gully eroded along a north-trending fault. This appears to be an Eocene dextral shear fault, part of the same regime as the Thunder Lake Fault to the east. This is a popular tour-group stop.

**The Skagit Migmatites**

Just beyond the first tunnel, a roadcut displays the Skagit migmatites. These are a swirled mix of orthogneiss and paragneiss components, reflecting conditions at temperatures of about 700 degrees (C). Despite their appearance, the rocks have not actually been melted. They have been deformed and metamorphosed in the uppermost amphibolite facies, in a process involving water and other volatile fluids. Peak metamorphic conditions here were probably attained at about 75 Ma, at a depth of perhaps 25 kilometers. The best accessible examples of the Skagit Migmatites can be found around the base of Diablo Dam and the town of Diablo.

*Figure 68 (Above) Gorge Creek Falls*
Garnetiferous Gneiss

A half-mile beyond the second tunnel is a turn-out on the right. The large boulders on the periphery of the pull-out area here offer an opportunity to see the variety of gneisses which make up the Skagit “core” region here. Most of these are orthogneiss, but some (or sections of some) contain paragneiss components. On close inspection, some of the paragneiss sections contain garnets. These illustrate that metamorphism here is in the upper amphibolite facies.

Figure 69 (Right)

The Skagit Gorge, now drowned by the waters of Gorge Lake. See figure 6 (Page 5) for what this canyon used to look like. The waters impounded in this lake are diverted into two tunnels which carry the water to the powerhouse in Newhalem. Between the dam and the town, the bed of the Skagit is typically dry during the summer and fall months.

Outcrops of migmatites on the left.

Figure 70 (Right)

An outcrop of the Skagit migmatites. Migmatites are rocks which reflect the highest degrees of metamorphism, in a setting which usually includes large amounts of (superheated) fluids such as water. Despite their appearance, these rocks have not been “melted” in this process.

This outcrop location is seen in the figure above. There is no roadside parking on this section of the highway.
Diablo Road intersection, Bridge over Gorge Lake

Diablo is a company hamlet of Seattle City Light, to service Diablo and Ross Dams above. Diablo Dam was completed in 1936, Ross Dam in 1952. Diablo Dam was built in what was formerly called Diablo Canyon. The name is Spanish for “devil,” as early miners used to call it the “devils punchbowl”. This is where Thunder Creek used to cascade into the Skagit.

Keep right on Highway 20

Intersection with the Diablo Dam Road

Remain on Highway 20

Roadcuts in Skagit Paragneiss

The rocks here are paragneiss, the high-grade metamorphic equivalents of the original Chelan Mountains (Naقاءqua, Cascade River) Terrane. This is one of several large “rafts” of these original rocks which remain in the Skagit Gneiss Complex. They have been invaded in several intrusive episodes. These appear to be metasedimentary and metavolcanic varieties, with none of the ultramafic components characteristic of the Naقاءqua rocks. A few hundred feet to the south, a block of marble is preserved. These may have originally been rocks of the Cascade River Group.

Figure 71 (Below)

View (looking south) showing various features in the Diablo Lake area. Base image from Google Earth
Thunder Lake

Thunder Lake lies in a depression eroded along the north-south trending Thunder Lake Fault. As described below, this is an Eocene feature displaying a right-lateral sense of displacement. It appears to have been active in accommodating local shear generated along the larger Fraser (Straight Creek) Fault some 20 km to the west.

Colonial Creek Campground
*Watch for pedestrian traffic*

This is a large campground / RV complex, and the highest roadside campground on the west side. In its construction, the Park Service diverted the course of Colonial Creek to a more convenient location for that project. On a regular basis the creek reverts to its rightful course, destroying part of the campground.

Bridge over Diablo Lake

The valley heading south from here is Thunder Creek, one of the major tributaries of the Skagit. It heads on Park Creek Pass, some twenty miles to the south, which heads on the Stehekin River. The Thunder Creek Valley drains a large region which retains an extensive glacial cover. The milky color of the lake reflects an abundance of suspended glacial clay and silt. Back in the early 1960’s this valley was the proposed site of a hydroelectric dam and reservoir complex, a project that was eventually shelved with the creation of the National Park in 1968.

This part of Diablo Lake is called Thunder Arm, as it impounds the lowest part of the Thunder Creek Valley. Prior to construction of Diablo Dam, the “creek” (actually, a very substantial river) cascaded down a canyon here to meet the Skagit River below. The thunderous roar of this cataract was the source of the creek’s name.

![Figure 72](Above)

Outcrops of paragneiss, just beyond the Diablo Dam road. These are the metamorphosed remains of the original volcanic-island and ocean-floor rocks of the Insular Belt, and are largely metavolcanic and metasedimentary varieties. Metamorphism occurred during the Coast Range Episode, here between 80 and 60 million years ago. Rocks of this nature only make up about 20% of the Skagit region, the rest being gneisses of plutonic origins. These rocks are preserved as “rafts” of paragneiss, within the much larger orthogneiss province.

![Figure 73](Left)

Diablo Dam. This structure was completed in 1930, and was generating power by 1936. When completed, it was the highest concrete dam in the world, at 389 feet.
Stop 5 Diablo Overlook

Restrooms

This is a fine vantage on the Diablo Lake area. Across the valley, the peaks (from left to right) include Davis Peak (2149m / 7051’), Elephant Butte (2249m / 7380’) and Sourdough Mountain (1816m / 6106’). All of these peaks are comprised of the Skagit Gneiss, a product of the Late Cretaceous Coast Range Orogen. Nearly 80% of the rock here is orthogneiss, representing the vast quantities of tonalite (quartz diorite) intruded by the Coast Range Arc. These magmas intruded country rock largely consisting of the Napeequa (Bridge River) and Cascade River (Cadwallader) Terranes. These rocks were metamorphosed and preserved as “rafts” of paragneiss within the intrusive orthogneiss. Here in the Skagit region, maximum orogenic development was likely achieved by ~75 Ma.

The outcrop across the highway is a biotite – hornblende quartz diorite orthogneiss. While these rocks have been metamorphosed, most are largely directionless. They appear to date from 65- 70 Ma, making them relatively young for the Skagit suite. By that date, deformation had apparently ceased at this level. Several different orthogneisses are present here, cut by sills and dikes of various ages. The most recent features are the large light-colored dikes which cut all other rocks. These are pegmatite dikes of the Challis episode, and they are found over a broad section of the Skagit region. It may be that a large Challis-age pluton intruded underneath this area, and these dikes radiate from its cupola (top). These dikes have been dated at about 45 million years ago.

The orientation of the light-colored (Challis) dikes illustrates that we are in the center of a large fold which is a central feature to the Skagit region. These rocks were folded at about 50 Ma, a few million years before the dikes were intruded. The dikes on the east side of the outcrop trend upwards, the dikes on the west side trend downwards. Collectively, they illustrate that we are in the center of this regional-scale feature.
Just west of here, Thunder Arm of Diablo Lake heads on Thunder Creek. Thunder Creek is a large drainage with an unusual north-south orientation (most features here are oriented NW – SE). The Thunder Creek Valley is cut along a set of north and northwest-trending faults which control its orientation. The master fault of this set is the Thunder Creek Fault, which can be seen cutting through the east ridge of Colonial Peak at a prominent notch. It continues north through Thunder Lake on the other side of the hill across Diablo Lake, and across the Skagit to form the valley of Sourdough Creek on the far slopes. The Thunder Lake Fault is an Eocene (Challis) feature which cuts (and is therefore younger than) the 45 Ma dikes seen here. It is in turn cut by the ~36 Ma rocks of the Chilliwack Batholith to the north. The fault is a right-lateral strike-slip feature, likely driven by concurrent movement on the Fraser (Straight Creek) Fault to the west. It was probably active from ~44 – 40 Ma.

Figure 75 (Above) The extensive road-cut at the Diablo overlook. The orientation of the (45 Ma) light-colored dike rocks illustrates that this locale is the center of the regional Skagit Antiform (fold crest). This folding appears to have occurred between 50 and 48 million years ago. The trees have grown considerably since this image was taken.

Figure 76 (Left)
Image showing features of the Diablo Lake area. White arrow points to the location of the Diablo Overlook. Note the distinctive U-shaped profile of the Thunder Creek Valley, to the rear.

The yellow line illustrates the location of the Thunder Lake Fault, part of a system of faults which developed concurrent with motion on the larger Fraser Fault to the west. Displacement on this fault is about 10 km, with the west side moving to the north.
The most dramatic development here in recent (geologic) time concerns the origins of the upper Skagit drainage. Three million years ago, prior to the recent ice ages, the ancestral Skagit River had its origins on a divide located roughly where Diablo Dam now stands. Above that divide, what is now the upper Skagit originally drained north into Canada, down this wide, low-gradient valley. As the earliest episodes of continental glaciation commenced, a large valley glacier descended south out of Canada, flowing (what was then) up the upper Skagit Valley. As it did, it impounded a large lake here, much like modern day Ross Lake and Diablo Lake. Eventually, that lake overtopped the divide and drained west into the ancestral Skagit River. These waters cut through the divide, and cut the deep Skagit Gorge into what was originally a headwater valley. As the glacier finally retreated, the valley floor had been lowered enough that the upper portion now flowed south and west into the Skagit, reversing its original course.

Figure 77 (Above) View from the Diablo overlook. The top of Diablo Dam can be seen at water-line.

Figure 78 (Right) Jack Mountain, to the east, from the Diablo Overlook.
Figures 79-82 (this spread)

Images illustrating the evolution of the Skagit drainage over the recent ice-ages. Base images from Google Earth.

(Left) The Skagit drainage prior to the recent ice-ages. Note that the lower Skagit heads on a divide above modern-day Newhalem. The upper Skagit is a separate system, draining north to the Fraser River in British Columbia.

(Left) The Skagit Drainage as the continental ice-cap advances south during the recent ice ages. Over the last two million years, this has probably happened dozens of times.
(Right) Dammed by the advancing icecap, a lake forms in the upper Skagit drainage. This lake rises until it overtops the divide at the head of the (lower) Skagit, and flows west by that course.

(Right) The Skagit drainage after the early ice-ages. Waters draining from the lake in the upper basin have cut the Skagit Gorge between the two river systems. The course of the upper Skagit has now been reversed, flowing west to the Puget Sound.
Many of the remote summits of the upper Skagit region were the sites of fire lookouts through the 1950’s. In that last decade, some of these were manned by people like Gary Snyder, Philip Whalen and Jack Kerouac. These were the avant-guard poets of the “beat generation”, taking their inspiration from the rugged grandeur of this spectacular region. In time, their works have become widely acclaimed. Gary Snyder manned the station at Sourdough Mountain.

*Continue east on highway 20*

**Stop 6 Migmatitic Skagit Gneiss (John Pierce Falls)**

The Skagit region is broadly antiformal in structure, striking to the north. At this point we are in the center of the antiform, and thus in the deepest part of the Coast Range Orogen here. The rocks here are spectacular banded migmatites (rocks which have the appearance of being partially melted). These are rocks which were subjected to temperatures of over 750 C and pressures equivalent to burial at over 25 km. They were not melted, but were deformed and metamorphosed extensively in the presence of high temperature / high pressure fluids like water and carbon dioxide. These events took place at the height of the Coast Range Orogeny in this area, probably about 75 million years ago. At that time, this region would have been the base of the thick pile of igneous rocks accumulated above the Coast Range Arc.

The rocks here are a mix of orthogneiss (meta-igneous) and paragneiss (metasedimentary or metavolcanic) types, but a mixing of components during metamorphism has produced all manner of intermediate forms. Much of the rock has been recrystallized as a banded gneiss, where the (light) felsic and (dark) mafic components have become segregated into distinct layers. The most distinctive features here are pods of metamorphosed ultramafic (mantle) rock, typically tan to green in color. The chemical reactions between the magnesium-rich ultramafic rock and the potassium, aluminum and silicon-rich surrounding rocks produce silvery talc, green tremolite, and actinolite, tan phlogopite (a mica) and other diagnostic minerals. The presence of ultramafic rock suggests that the Napeequa (Bridge River) Terrane is the major paragneiss component here. Tectonic slices of ultramafic mantle rocks are common within the Napeequa Schist.

This was the last major section of Highway 20 to be completed. Getting the long steel beams for this bridge up the Skagit Gorge was a major challenge. Started before the National Park was created, the road was subsequently dubbed the “North Cascades Parkway” when it was completed in 1972. John Pierce was a prominent highway booster. This feature was formerly known as “Horseshoe Falls”.
Figure 84 (Right)

Roadside outcrop just above John Pierce Falls.

Figure 85 (Below)

A classic section of migmatite in the outcrop above. Rocks of this character represent the highest conditions of metamorphism.
Figures 86, 87 (this page)
Exposures of banded gneiss and migmatite at this outcrop. The rocks here reflect repeated intrusive events, displaying cross-cutting relationships on a number of scales.
Stop 7  Ross Lake Overlook  
Elevation 2200’  660m

The view here is of Ross Lake, impounded behind Ross Dam. The lake extends north across the international border. The prominent peaks on the east side of the lake include (right to left) Little Jack, Jack and (far in the distance) Hozameen Mountains. These peaks lie within the Ross Lake Fault Zone, Hozameen rising along its eastern margin. The western margin of that zone, the Ross Lake Fault itself, cuts across Ross Lake on a NW trend about 5 miles up the lake. Mt. Prophet (7650’ 2330m), the highest summit to the right of the lake, is cut from marble, paragneiss and orthogneiss of the Skagit suite. The outcrop on the far side of the road is composed of migmatites of the Skagit suite. The Ross Lake Fault Zone is a fundamental terrane-bounding feature between the rocks of the Intermontane Belt to the east, and the Insular Belt to the west.

Figure 88 (Right)

Image showing Ross Lake, with the locations of Ross Dam, the Ross Lake Overlook, and the names of several mountain peaks. View looks north.

The yellow line represents the location of the Ross Lake Fault, the western margin of the Ross Lake Fault Zone. This zone is the tectonic “suture” between the Insular Belt and the Intermontane Belt to the east.

Base image from Google Earth.

Figure 89 (Right)

Mount Prophet, from the Ross Lake overlook. This peak is comprised of rocks of the Skagit Gneiss. It displays the classic features of a glacially-sculpted peak.
While the amount of right-lateral displacement across the Ross Lake Zone is open to interpretation (relationships do not necessarily require such motion), the contrasts in metamorphic grade across the northern end of the Ross Lake Fault requires a substantial amount of post-metamorphic, west-side-up, normal displacement. This likely took place between 75 and 60 Ma, in a period of rapid uplift and unroofing of this region.

The broad north-trending valley of the Upper Skagit was a major corridor for glacial ice moving south out of Canada during the Pleistocene episodes of continental glaciation. While some ice did turn west here down the Skagit, most of it continued south up the valley of Granite Creek. The rounded eastern shoulders of the Skagit Valley just above Ruby Creek show the erosive effects of a vast river of ice moving south through here.

Ross Lake and Ross Dam honor J.D. Ross, the superintendent of Seattle City Light who oversaw development of the Skagit River Hydropower Project. (originally, it would have been Ruby Dam and Ruby Lake). Prior to the construction of Ross Dam in 1952, the Skagit River ran down a broad, deep, low-gradient valley through here. At an elevation of less than 1500 feet, this lowland valley was a critical winter habitat for a large number of species. Over 340 million board feet of timber were removed as the lake was filled.

The valley now occupied by the lake was a very popular hunting and gathering area for the local native tribes. In contrast to the sharp boundaries which usually marked their domains, this valley appears to have been a common locale for the Lower Thompson, Chilliwack, Nooksack, Stilligumish, Chelan and other tribes. Hunting and trading parties from as far as the Similkameen used to travel to this area. Archeological evidence suggests that people arrived here by 9 - 10,000 years ago, with the heaviest occupation dating from 5000 – 3500 years ago.

The waters of Ross Lake also cover the site of a historic mining camp at the mouth of Ruby Creek. Placer deposits here spurred a succession of “gold rushes” to this area in the 1870’s and 1880’s. Owing to the difficulty of the ap-
proach up the Skagit Gorge, most of the miners came south out of Canada or east from the Okanogan. The camp here was known as Ruby City. The creek takes its name from early prospectors, who found garnets (“rubies”) here.

*Turn around and return west on SR 20*

**Stop 9 The Chilliwack Batholith**

The roadcut here is in the Chilliwack Batholith, a Cascade Arc intrusive complex. The rock is a hornblende-biotite tonalite (granodiorite), fairly typical of the Cascade Arc intrusions. This particular body has been dated at ~30 Ma, and is part of the “Mt. Despair” Pluton. Note that compared with plutons of the Coast Range Episode, the Chilliwack is unmetamorphosed and undeformed. It was intruded at a relatively shallow depth of 3-5 km, likely rising along the adjacent Straight Creek (Fraser) Fault.
Cascade Arc plutons are exposed throughout the North Cascades, while the area south of Snoqualmie Pass is largely characterized by volcanic cover. This reflects the south-dipping character of the uplift of the modern range. Greater uplift to the north has exposed the deeper plutonic “roots” of the Cascade Arc here. Five million years ago, this pluton was about 2.5 km deep in the crust.

This pluton is one of several dozen intrusive bodies which rose along the Straight Creek (Fraser) Fault to the north of here. These plutons range in age from 36 to about 10 million years ago, and hosted a succession of volcanoes on the surface. Consequent to changes in plate dynamics at about 7 Ma, the axis of the Cascade Arc has since moved west into the Mt. Baker – Garabaldi belt. The 7-3 Ma plutons of the Chilliwack series show a progressive westward migration over this period.

Continue west on Highway 20 to Interstate 5.
Diagram illustrating the evolution of the Chilliwack Batholith. The plutonic (granite-type) rocks which make up this large body accumulated as the “roots” of volcanoes which developed here from 36 to 10 million years ago.

With the uplift of the modern Cascade Range, about 3 km of erosion has exposed these deep rocks in the modern landscape.
A Few References

There are few good resources for expanding on one’s understanding of the geology of this region. The following is a brief list for the introductory student

Tabor, R.W and Haugerud, R. (1999) Geology of the North Cascades, A Mountain Mosaic. The Mountaineers, Seattle,
Written by the two leading geologists to this area, this book is a good guide to the rocks and geography of the region. An excellent resource for anyone who does a lot of hiking in this area.

Much of the information in this book can be found on the National Park Service Website for the North Cascades.

Burke Museum Website on the Geology of Washington www.washington.edu/burkmuseum/geology_wa
Written for the general public

A current textbook of Pacific Northwest Geology. 350 pps
Available (free) on-line at www.northwestgeology.com
The Pacific Northwest is home to some of the most remarkable geology to be found anywhere on the planet. No region can claim to a greater variety of rock types, or features them in more spectacular settings. More significantly, no region affords such a remarkable venue on the truly colossal forces which drive the dynamics of our planet, or such graphic illustrations on the variety of geologic processes which they support. There is simply no better place on the planet to see how the Earth works. There is certainly no better place on Earth to learn and experience geology.

If you are planning on living in this area, you should know that you are living in the midst of some of the most incredible geology in the world. You should know that the modern landscape that surrounds you is the product of a truly amazing course of geologic history, one that stretches back hundreds of millions of years. You should recognize that you occupy a unique point in time and space in that course of history, and in the ongoing geologic processes which will continue to shape this region into the future.

John