Field Guide
to the Mesozoic Accretionary Complex in Kachemak Bay and Seldovia, South Central, Alaska

Alaska Geological Society
Field Trip 2000
May12 - 15, 2000

Trip Leaders:
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FIELD GUIDE TO THE MESOZOIC ACCRETIONARY COMPLEX IN KACHEMAK BAY AND SELDOVIA, SOUTH-CENTRAL ALASKA

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INTRODUCTION

The shorelines of Kachemak and Seldovia Bays, southern Kenai Peninsula, provide superb exposures of Alaska's Mesozoic accretionary wedge. Although none of these outcrops can be reached via the main road network, they are reasonably accessible by Alaskan standards: those along Kachemak Bay can be reached within a few hours by boat from Homer, seas permitting, and those in Seldovia can be reached by local roads and trails. This field trip will visit a series of outcrops that we studied between 1989 and 1993 during geologic mapping of the Seldovia 1:250,000-scale quadrangle as part of the USGS Alaska Mineral Resource Assessment Program (Bradley and others, 1999), and from 1997 to present as part of a National Science Foundation project.

REGIONAL GEOLOGY

Peninsular Terrane and Cook Inlet Basin

Alaska's Pacific margin is underlain by two parallel terranes — the Wrangellia composite terrane (consisting of the Peninsular, Wrangellia, and Alexander terranes), and farther outboard, the Chugach-Prince William terrane. During much of the Mesozoic, the two formed a magmatic arc and accretionary wedge, respectively, above a circum-Pacific subduction zone.

Rocks assigned to the Peninsular terrane occupy a roughly 3 x 10 km area at the southwestern tip of the Kenai Peninsula; we will float past exposures of these en route to Seldovia. These rocks have been described in a previous guidebook of the Alaska Geological Society (Kelley, 1985). The oldest strata, assigned to the Upper Triassic to lowermost Jurassic Port Graham Formation, consist of dark-gray carbonaceous limestone and silty limestone; also present are minor tuff, tuffaceous sedimentary rocks, and chert (Kelley, 1980). The Port Graham Formation is at least 1,500 m thick; the base is not exposed. The overlying Talkeetna Formation, which will be seen at Stops 6 and 7, consists of at least 5,270 meters of andesite and dacite tuff, volcaniclastic conglomerate, sandstone, and mudstone, and minor coal and limestone. Kelley (1980) assigned these same rocks to an informal unit—the Pogibshi Formation—but subsequently (oral communication, 1988) recommended that they be included in the Talkeetna Formation. A dioritic pluton and satellite dikes intrude the Peninsular terrane at Point Bede; the pluton is undated but presumed to be Jurassic.

Cook Inlet Basin is an active forearc basin built on older forearc and arc rocks of the Peninsular terrane. The Tertiary section is nearly 8 km thick in the deepest part of the basin. Three Tertiary units, all fluvial, are exposed along the shores of Kachemak Bay (Magoon and others, 1976; Reinink-Smith, 1995). Weakly consolidated sandstone and conglomerate assigned to the

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Tyonek Formation (Oligocene to Miocene) is exposed along Barabara Beach (Stop 5). The bluffs at Homer are formed from coal-bearing strata of the Miocene Beluga Formation. The bluffs at the northern end of Kachemak Bay are underlain by coal-bearing strata of the Miocene to Pliocene Sterling Formation.

Chugach-Prince William Terrane

The accretionary wedge of south-central Alaska (fig. 1) includes both Mesozoic and Cenozoic parts. The inboard, Mesozoic part has been referred to as the Chugach terrane and the outboard, Cenozoic part as the Prince William terrane (e.g., Coney and others, 1980). This distinction has been shown to be artificial (Dumoulin, 1988), and is perpetuated by convenience rather than merit. Here we use the term "Chugach-Prince William terrane".

In the field trip area, the farthest inboard rocks of the subduction complex belong to the Seldovia metamorphic complex, which occupies a narrow fault slice just north of Seldovia village. Stops 8B, 9, and 10 will feature various parts of the metamorphic complex. As discussed more fully under the description for Stop 8B, metamorphism took place in the Early Jurassic (191-192 Ma) under conditions of high pressure and low temperature—conditions that suggest metamorphism in a subduction zone.

The McHugh Complex, a tectonic mélange, flanks the metamorphic rocks on their seaward side. Its main components are argillite, graywacke, chert, and basalt; minor components are limestone, gabbro, and ultramafic rocks. These rock types are juxtaposed at all scales. In Seldovia quadrangle, the largest fault slices of chert, basalt, and graywacke are a few kilometers across and tens of kilometers long (Bradley and others, 1999). At the outcrop, hand-sample, and thin-section scale, these same rock types occur as more competent blocks or fault slices in argillite matrix. The applicability of the term "mélange" thus depends entirely on the scale. The predominant mode of early deformation in the McHugh Complex was layer-parallel fragmentation; breakup of relatively competent beds, such as chert and graywacke, was accompanied by flow of argillite matrix into gaps. The resulting fragment foliation is the most conspicuous fabric element in the McHugh Complex. The foliation is commonly displaced across narrow (up to a few centimeters wide), early ductile shear zones. Deformation of the McHugh Complex has been discussed by Bradley and Kusky (1992) and Kusky and Bradley (1999). Prehnite-pumpellyite metamorphic facies assemblages are typical (Bradley and others, 1999). The primary mélange foliation, ductile shear zones, and metamorphism are all believed to have formed during subduction-accretion.

Many new fossil ages have been reported from the McHugh Complex since the early 1980's. At several places, mostly in Kachemak Bay (fig. 2), radiolarian chert depositionally overlies pillow basalt (for example, Stop 3). Precise radiolarian ages show that the base of the chert varies from Ladinian (Middle Triassic) to Albian-Aptian (mid-Cretaceous)(C. Blome, USGS, written commun., 1994). Other chert sections, which are fault-bounded and have no stratigraphic context, also range from Ladinian to Albian. Graywacke depositionally rests on Pliensbachian (Early Jurassic) radiolarian chert at one location (C. Blome, USGS, written commun., 1994). Limestones within the McHugh Complex are of two types of very different origin: clasts in conglomerate and tectonic blocks in mélange. A limestone clast in McHugh conglomerate from Turnagain Arm yielded conodonts with a possible age range of late Meramecian to early Morrowan (Late Mississippian to Early Pennsylvanian; Nelson and others, 1986). This clast could have been shed from the Strelna Formation of the Wrangellia terrane (Nelson and others, 1986). Most of the dated limestones, however, are tectonic blocks—typically occurring as severely extended strings of boudins—that have yielded Permian fusilinids, conodonts, or both (Stevens and others, 1997; B. Wardlaw and A. Harris, USGS, written commun., 1994). The fusilinids and conodonts are of shallow-water, tropical, Tethyan affinity. Stevens and others (1997) noted that the fusilinids are quite distinct from those of Wrangellia.

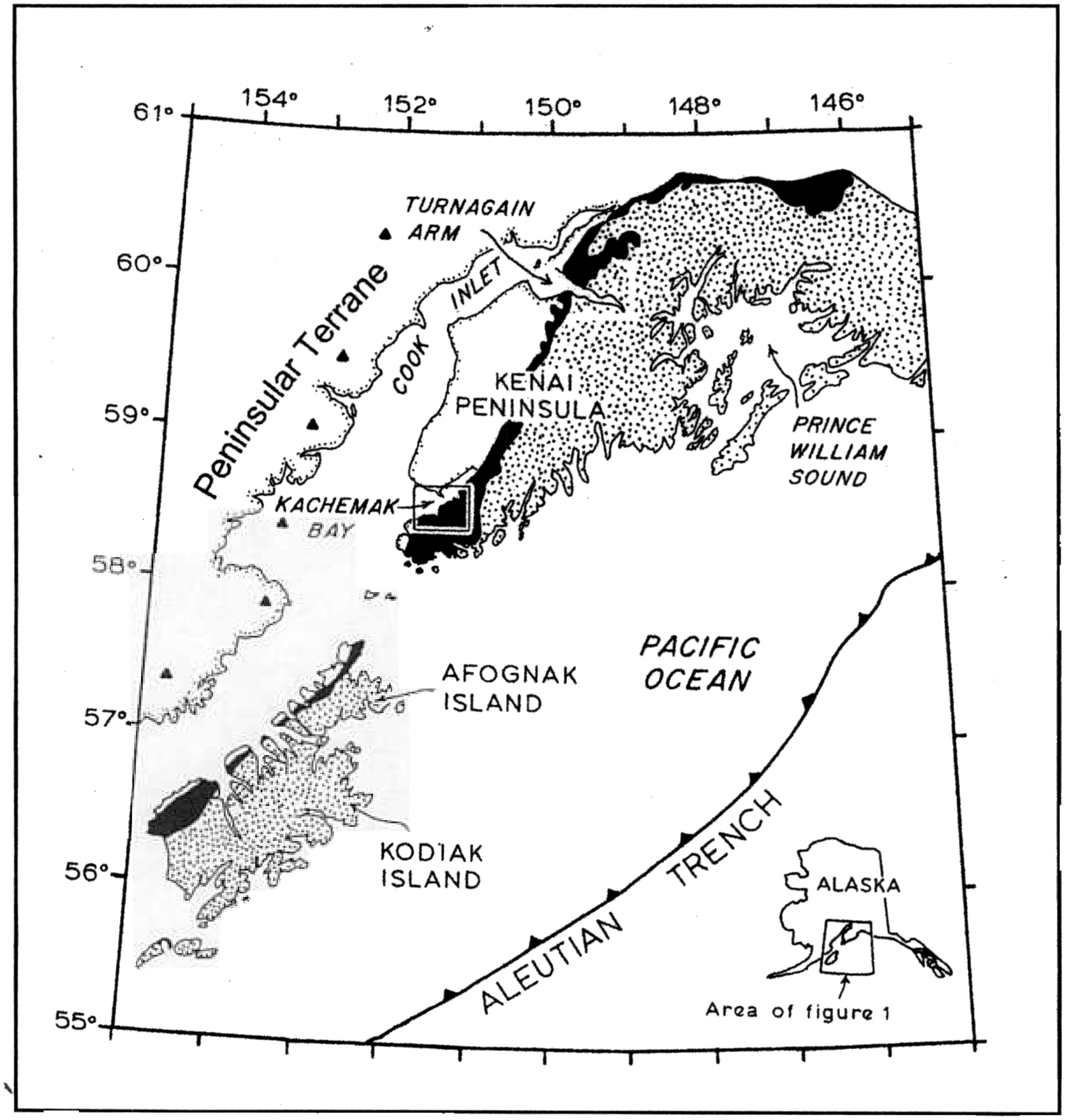


Figure 1. Simplified geologic map of the Kenai Peninsula and Cook Inlet. Box shows location of the field trip area in Kachemak Bay. Black pattern indicates McHugh and Uyak Complexes; stipple pattern indicates other rocks of the Chugach-Prince William terrane.

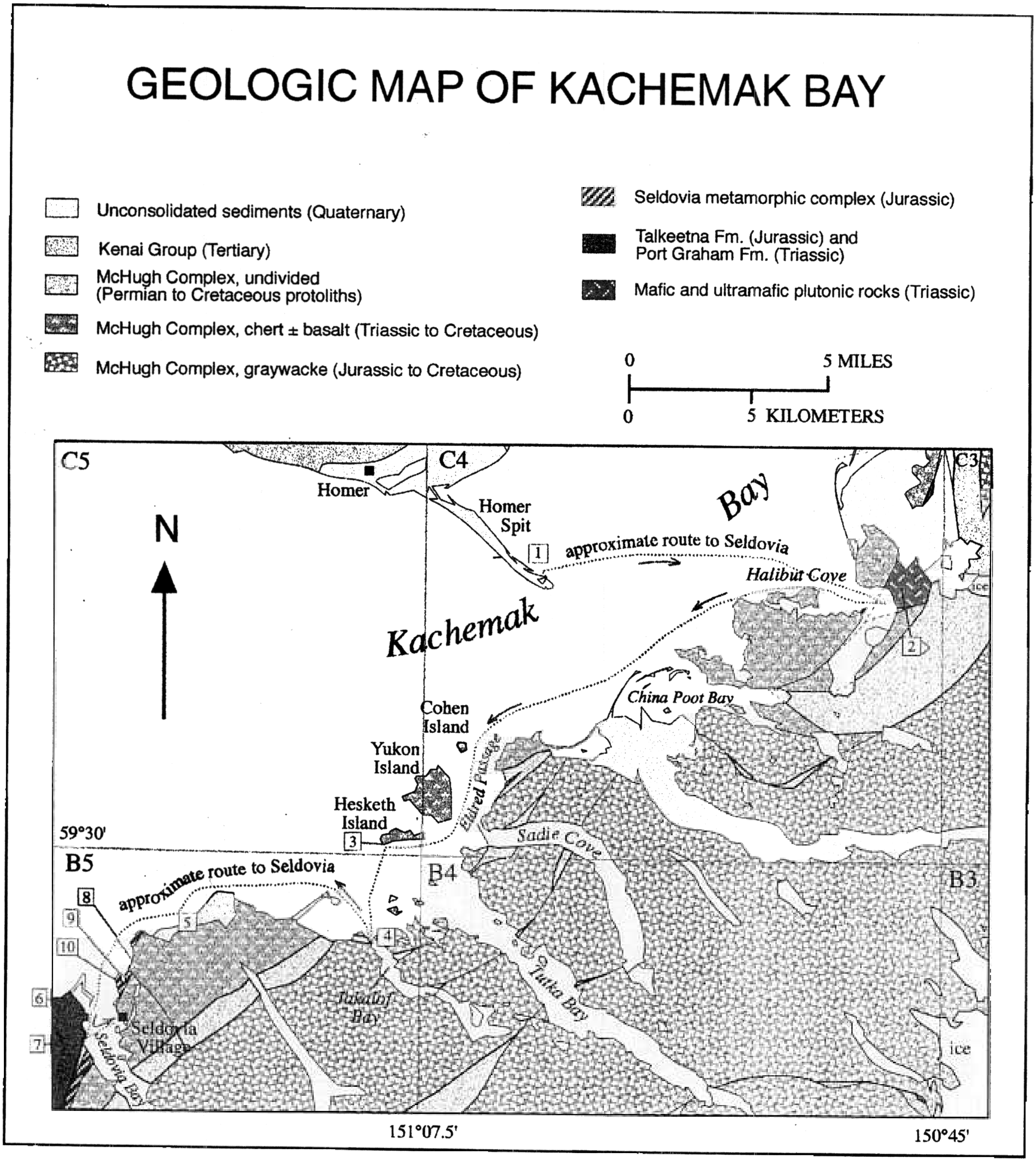


Figure 2. Geologic map of the field trip area, adapted from Bradley and others (1999) BRF is Border Ranges Fault.

The fossil ages are readily explained by a stratigraphic model developed by Connelly (1978) for the Uyak Complex, an equivalent of the McHugh Complex on Kodiak Island. According to this interpretation (figs. 3 and 4A), the McHugh Complex basalts were formed by seafloor spreading, the overlying cherts were deposited on the ocean floor as it was inexorably conveyed toward a trench, and the argillite and graywacke record deposition on the downgoing plate in the trench, just prior to subduction-accretion. The fact that depositional contacts between basalt and chert are of various ages is predicted by this model; the chert-basalt contact is simply time transgressive. Alternatively, it is also possible that the oceanic section that was conveyed into the subduction zone included several interstratified basalt and chert units (fig. 4B), basalt intervals above the oldest one having been erupted from off-axis volcanoes. In either model, the tectonic limestone blocks might represent the tops of seamounts that were decapitated at the subduction zone. If so, some of the ocean floor that was incorprated into the McHugh Complex would necessarily date back to the Paleozoic, as a seamount cannot be older than the ocean floor on which it is built. It should be noted, however, that no Paleozoic radiolarian chert has yet been recognized in the McHugh Complex. The timing of subduction-accretion is suggested by various lines of indirect evidence and reasoning. Early Jurassic (191-192 Ma) metamorphism of the Seldovia metamorphic complex indicates subduction during that time, and subduction-related magmatism along the Peninsular terrane could have been underway as early as Late Triassic, as is suggested by tuffs in the Port Graham Formation. The youngest fossils from the McHugh, Albian radiolarians, indicate that at least some subduction-accretion took place after these were deposited at the end of Early Cretaceous time, somewhere seaward of the trench . By the same reasoning, some graywacke deposition likely postdated the youngest chert. Hence, based on evidence from the Seldovia quadrangle, the interval(s) of subduction-accretion that built the McHugh accretionary complex most likely lasted from Late Triassic to Late Cretaceous.

The Valdez Group of Late Cretaceous (Campanian? to Maastrichtian) age flanks the McHugh Complex on its seaward side. It is not exposed in the field trip area except, perhaps, as blocks in mélange (Stop 8A), but a few facts are pertinent. In the Seldovia quadrangle, it consists of medium- and thin-bedded graywacke turbidites, black argillite, and minor pebble to cobble conglomerate (Bradley and others, 1999). Sandstones of the Valdez Group are moderately well sorted, and consist mostly of quartz and feldspar, some volcanic fragments, and rare chert. These strata were probably deposited on the downgoing plate in a deep-sea trench (Nilsen and Zuffa, 1982), and accreted shortly thereafter. The McHugh Complex was structurally emplaced above the Valdez Group along a thrust fault, known as the Chugach Bay thrust. Beneath the fault is a mélange of partially to thoroughly disrupted Valdez Group turbidites (Kusky and others, 1997a).

Early Tertiary Ridge Subduction

Global plate reconstructions imply that a spreading center was subducted somewhere along the western margin of North America during the early Tertiary (Atwater, 1989). A series of near-trench plutons in the Chugach-Prince William terrane probably tracks the position of the resulting trench-ridge trench triple junction, (Bradley and others, 1993; and in press). These intrusions, the Sanak-Baranof belt of Hudson (1983), extend from Sanak Island on the west to Baranof Island on the east (fig. 5A). The near-trench magmatic pulse migrated 2,100 km along the continental margin, from Sanak Island in the west at 61 Ma, to Baranof Island in the east at 50 Ma; in the Seldovia area, the magmatism took place around 57 to 53 Ma (Bradley and others, in press). It is difficult to envision a plausible mechanism — other than ridge subduction — for generating intrusions in a near-trench setting with such a large-scale diachronous trend in ages.

A number of geologic features in the Chugach terrane that post-date accretion can be interpreted as products of ridge subduction. According to this model (fig. 5B), when the spreading center was subducted, an asthenosphere slab window opened in the widening gap between the subducted, but still diverging, plates. This brought hot mantle into contact with the cold, wet base of the accretionary prism, causing, at various depths, partial melting, high-temperature

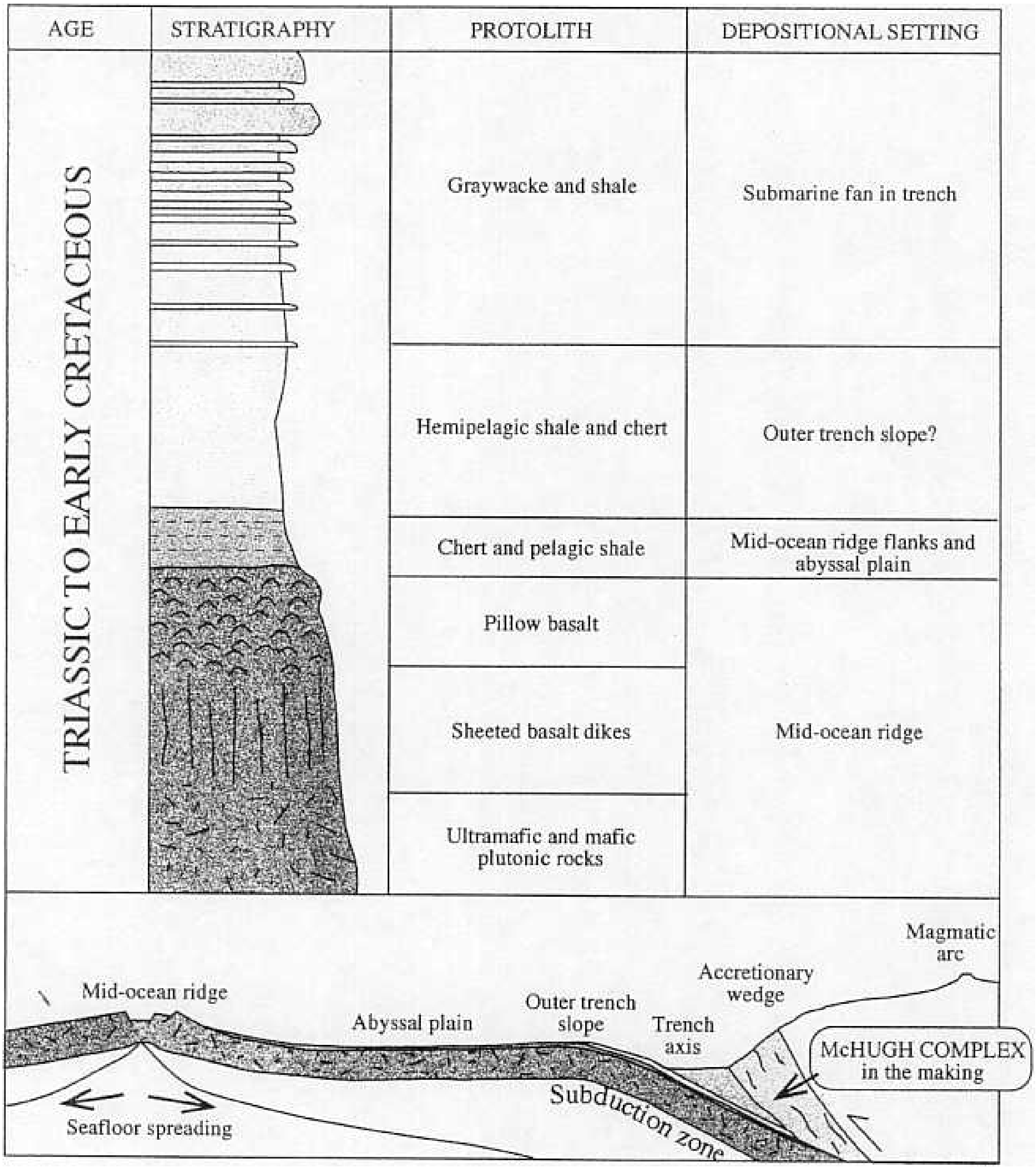


Figure 3. Conceptual model for igneous and sedimentary components of the McHugh Complex, after Connelly (1978).

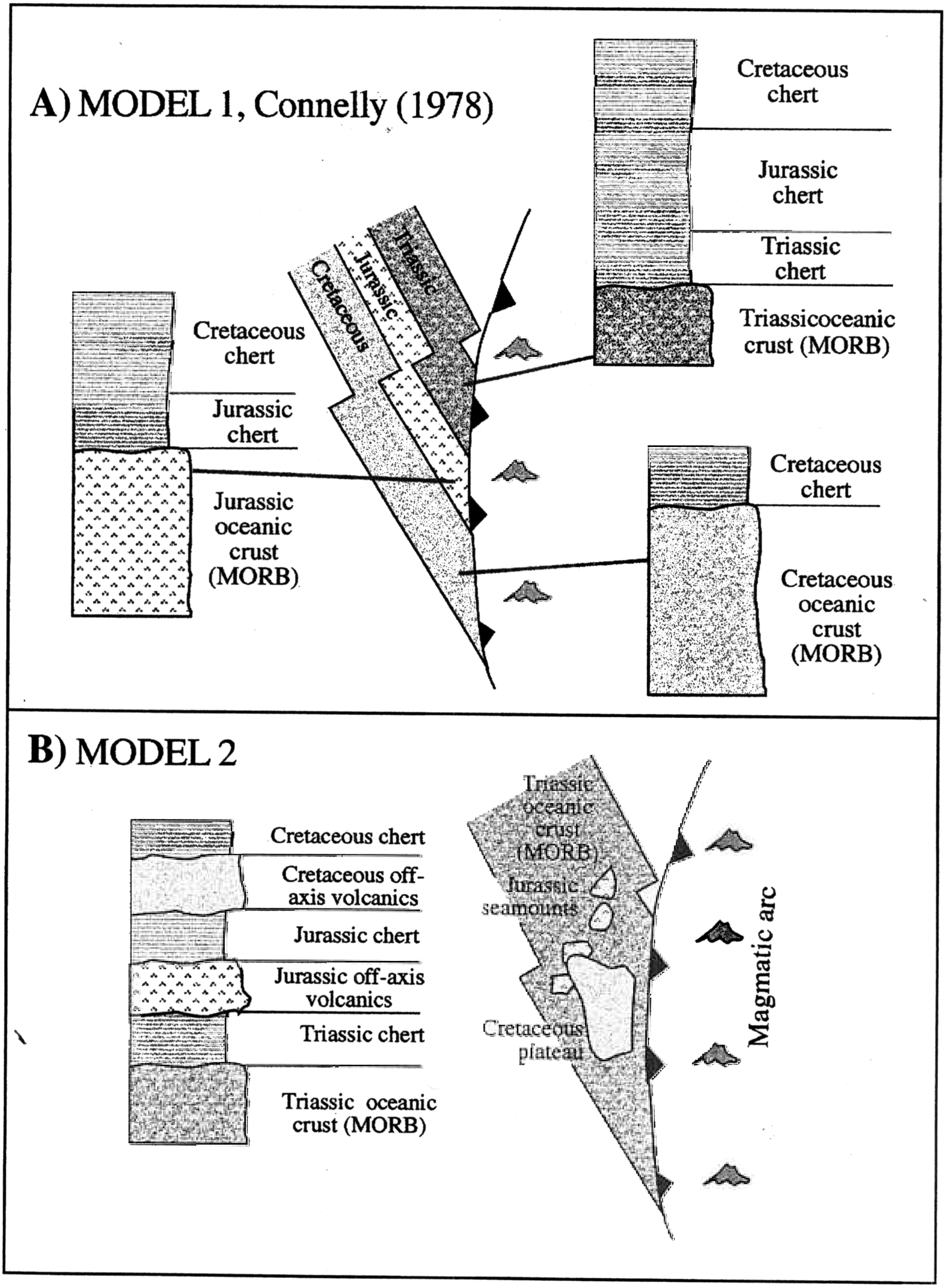
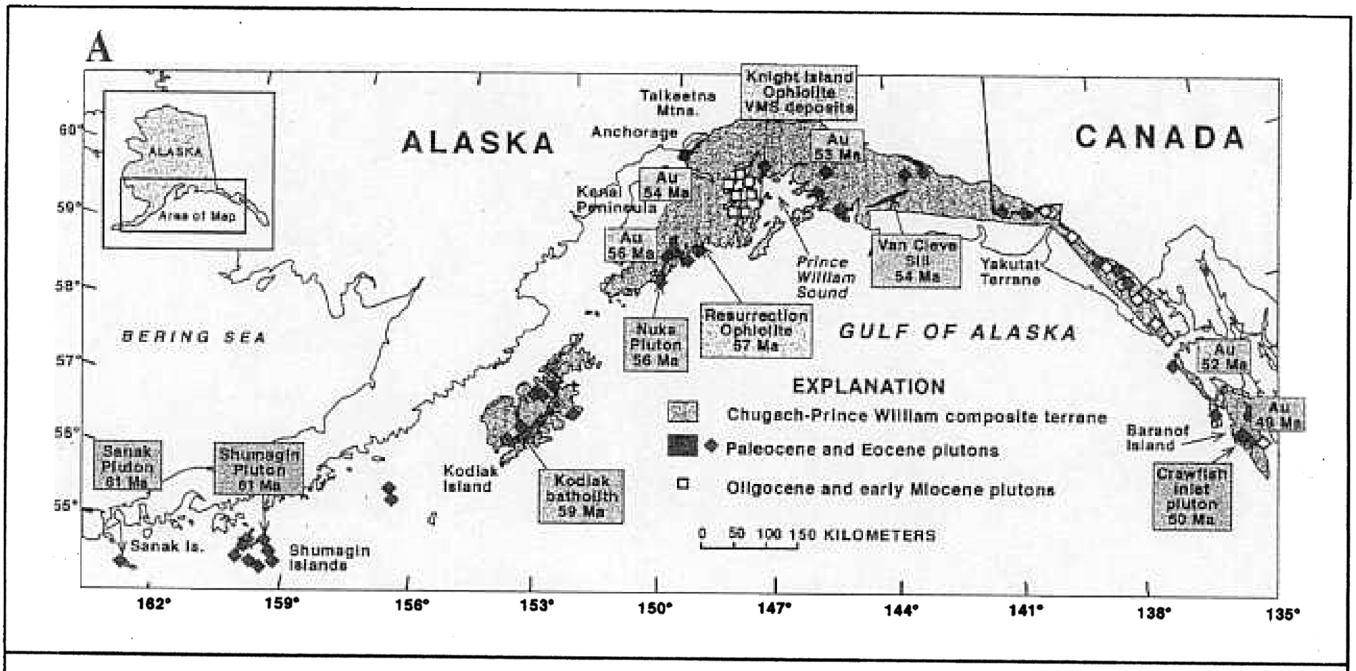


Figure 4. Possible alternative explanations for depositional and age relations between McHugh cherts and basalts.



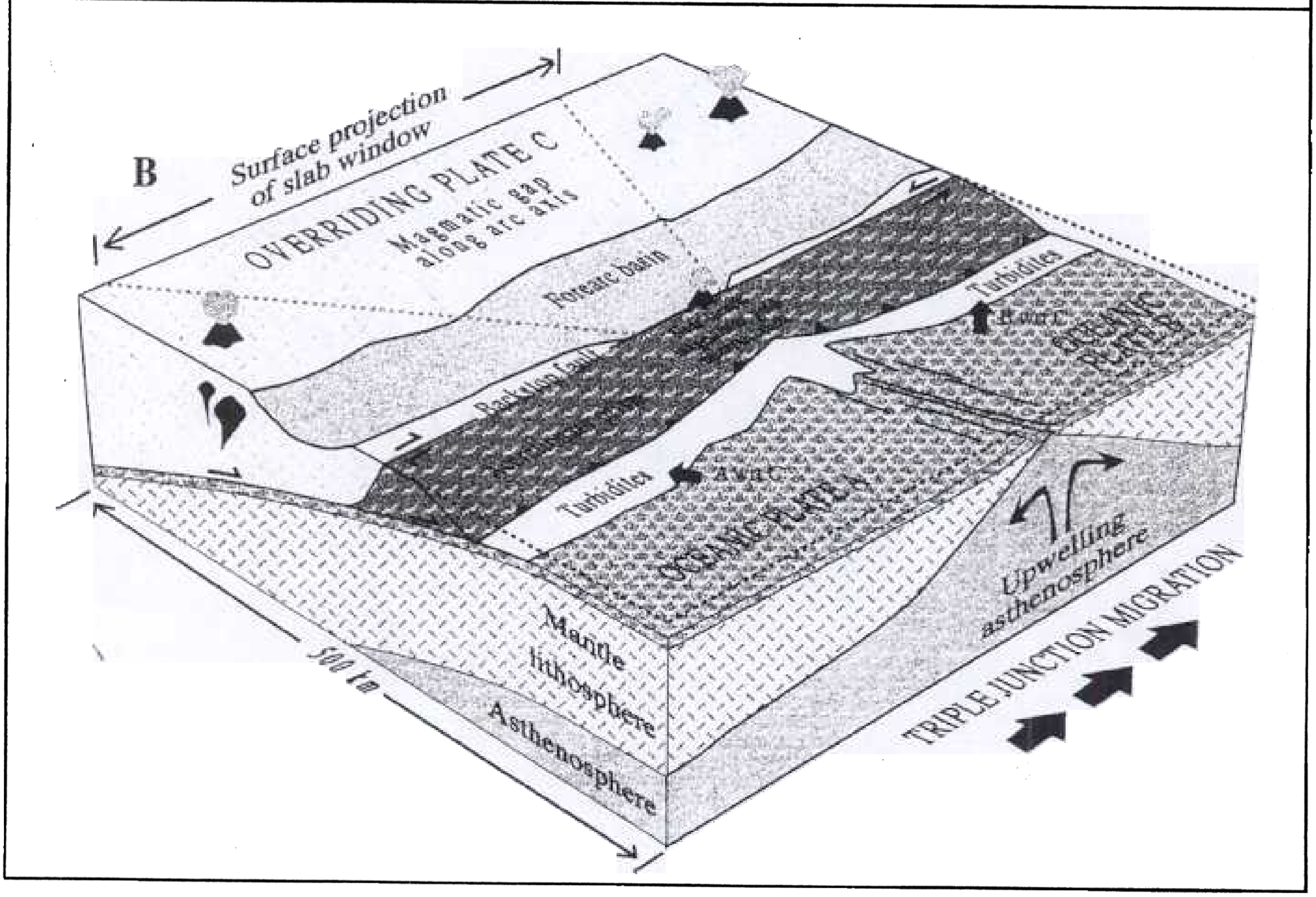


Figure 5. A) Map showing the distribution and ages of near-trench plutons and gold deposits believed to be related to subduction of a spreading center beneath the Chugach-Prince William terrane during early Tertiary time. B) Block diagram illustrating the geologic consequences of subduction of a spreading center.

metamorphism and— as we have emphasized, hydrothermal fluid migration and gold mineralization (Haeussler and others, 1995). As the high-standing spreading ridge approached a point along the continental margin, the accretionary prism was internally shortened along late thrust faults, thereby achieving a new critical taper. Then, as the triple junction migrated past and progressively older ocean floor was subducted, the accretionary prism was extended on normal and strike-slip faults (Kusky and others, 1997b).

FIELD TRIP IN KACHEMAK BAY AND SELDOVIA

The May 2000 Alaska Geological Society field trip will consist of two segments. The trip will begin with a circuitous boat ride from Homer to Seldovia, during which we will float past the first 7 numbered stops along the shores of Kachemak Bay and its tributary fiords. Some of these stops were described briefly in a 1997 guidebook article (Bradley and others, 1997). The size of the charter boat and the number of people on the trip will, unfortunately, prevent us from landing anywhere along the rugged shoreline. Future users of this guidebook should, however, be able to land at any of the numbered stops with a skiff or Zodiak. After reaching Seldovia, the remaining stops will be reached on foot by road and trails.

PART 1: HOMER TO SELDOVIA

STOP 1—Orientation at Homer Spit

On a clear day, Homer Spit provides a good view of the three main tectonic elements of the lower Cook Inlet region. (1) Volcanic arc: Mounts Augustine and Iliamna of the active volcanic arc tower over Cook Inlet, one hundred kilometers to the west. (2) Forearc basin: Cook Inlet and the Kenai Lowlands are part of the Cook Inlet forearc basin, which has subsided episodically since the Late Triassic. Looking northwest toward Homer, the bluffs are formed from the Miocene Beluga Formation, which consists of fluvial sandstone, fine-grained rocks, coal, and minor volcanic ash. Coal was mined intermittently between 1888 and 1951 (Barnes and Cobb, 1959). Total commercial production probably did not exceed a few thousand tons; some Homer residents still burn coal taken from the beach. (3) Accretionary wedge: The Kenai Mountains, on the southeastern side of Kachemak Bay, are underlain by the Mesozoic portion of the accretionary wedge—a feature that continues to form today at the Aleutian subduction zone.

Homer Spit itself is a modified end moraine, marking a terminal position of a Pleistocene glacier that occupied upper Kachemak Bay (Karlstrom, 1964). During the 1964 Good Friday earthquake, which shook Homer for about 3 minutes, the Spit subsided approximately 1.8 meters due to a combination of tectonic subsidence and compaction (Waller and Stanley, 1966). The worst economic damage was delayed for several weeks, when the Spit was inundated by higher than normal tides. The Salty Dawg Saloon, having withstood the quake itself, now had seawater pouring in through its windows.

Glaciers descending from the Kenai Mountains, across the bay, drain an ice cap that occupies the divide between the Pacific Ocean and Cook Inlet. The highest elevation in this part of the Kenai Mountains is at Truuli Peak (6612 feet, 2016 meters). Prior to Quaternary glaciation, the Kenai Mountains were at roughly their present height but were much less rugged; vestiges of the relatively subdued pre-glacial topography can be seen in the many accordant, flat-topped summits.

En route to Halibut Cove, the outcrops we will see are mostly of fault slices of Triassic and Jurassic chert and basalt, and a few slivers of graywacke, all of the McHugh Complex. Dacite and rhyolite dikes are conspicuous; they are Early Tertiary and interpreted as the product of ridge subduction.

STOP 2—Halibut Cove. The Halibut Cove gabbro, first described by Cowan and Boss (1978), crops out in a tall cliff at the northeastern end of Halibut Cove. The cliff face is sketched in figure 6, which shows the distribution of igneous rock types. Most of the body consists of gabbro, which is intruded by late-stage trondhjemite (plagiogranite). The southern end of the body consists of dunite, pyroxenite, and garnet pyroxenite; chromite and chrome-garnet are present. Along the shoreline just south of the mafic and ultramafic rocks, the McHugh Complex is cut by an intermediate porphyritic dike, presumably of early Tertiary age and related to ridge subduction. The gabbro is fault-bounded, and the surrounding McHugh Complex shows no sign of contact metamorphism, implying that the gabbro was "cold" when emplaced into its present structural position.

The Halibut Cove gabbro and pyroxenite is similar to several other mafic-ultramafic bodies on the Kenai Peninsula, all of which are bounded by faults and are surrounded by mélange of the McHugh Complex. The largest and most significant of these is Red Mountain, which will be visible, weather permitting, during the boat ride to Seldovia. Red Mountain, like the southern part of the Halibut Cove complex, consists of dunite and pyroxenite with chromite seams, and lesser quantities of garnet pyroxenite. The age of the mafic-ultramafic complexes of the Kenai Peninsula has been unknown until very recently. After processing several barren gabbros and gabbronorites for zircon and sphene, we finally were successful in separating zircon from a gabbro from Halibut Cove. The zircons were dated in Bob Tucker's lab at Washington University, and have yielded a preliminary Middle Triassic age of 230 Ma.

Two main hypotheses have been advanced to explain the origin of these mafic/ultramafic complexes. (1) They might represent the deep roots of a magmatic arc developed on the southern margin of Wrangellia (Burns, 1985), later thrust tens to hundreds of kilometers over the McHugh Complex, and now preserved as klippen. (2) Alternatively, they may represent segments of a thick oceanic plate off-scraped during subduction, either from "normal" oceanic lithosphere, an oceanic plateau, or an immature island arc (Kusky, 1997; Kusky and Bradley, 1999). The differences between these models are significant, and determining which is more likely to be correct is of paramount importance for understanding the Mesozoic-Cenozoic tectonic evolution of the Cordillera, and also for understanding the relative roles of arc magmatism vs. accretion of large igneous provinces in the growth of continental crust. The 230-Ma age reveals that the ultramafic massifs of the Kenai Peninsula are significantly older than the Jurassic arc rocks of the Peninsular terrane with which they were tentatively correlated by Burns (1985), but that they are the same age as the cherts and basalts of the McHugh Complex on the Kenai Peninsula. Accordingly, we lean toward hypothesis #2.

En route to the next stop at Hesketh Island, shoreline exposures consist largely of chert and basalt of the McHugh Complex, cut by innumerable faults. Beautiful exposures of contorted chert can be seen on Cohen Island (fig. 7A), Yukon Island, and Hesketh Island, and on a small island between Yukon and Hesketh (fig. 7B). Exposures on the mainland along Eldred Passage include chert, basalt, graywacke, gabbro, and mesoscale mélange. A riprap quarry in graywacke of the McHugh Complex is located on the point of land separating the entrances to Sadie Cove and Tutka Bay.

An important outcrop, which we will not have time to visit, is located on the south shore of Sadie Cove about 1 km east of the quarry. Graywacke depositionally overlies radiolarian chert that has yielded Pliensbachian (Early Jurassic) radiolarians (C. Blome, written commun., 1994). This relationship completes the classic "oceanic-plate stratigraphy" for the McHugh Complex (basalt-chert-graywacke/argillite), in support of Connelly's (1978) stratigraphic model (fig. 3). An analgous chert-graywacke section has been documented in the Franciscan assemblage (Karl, 1984). The Pliensbachian chert and graywacke section is bounded by mesoscale mélange interleaved with other fault slices of greenstone, graywacke, and bedded chert.

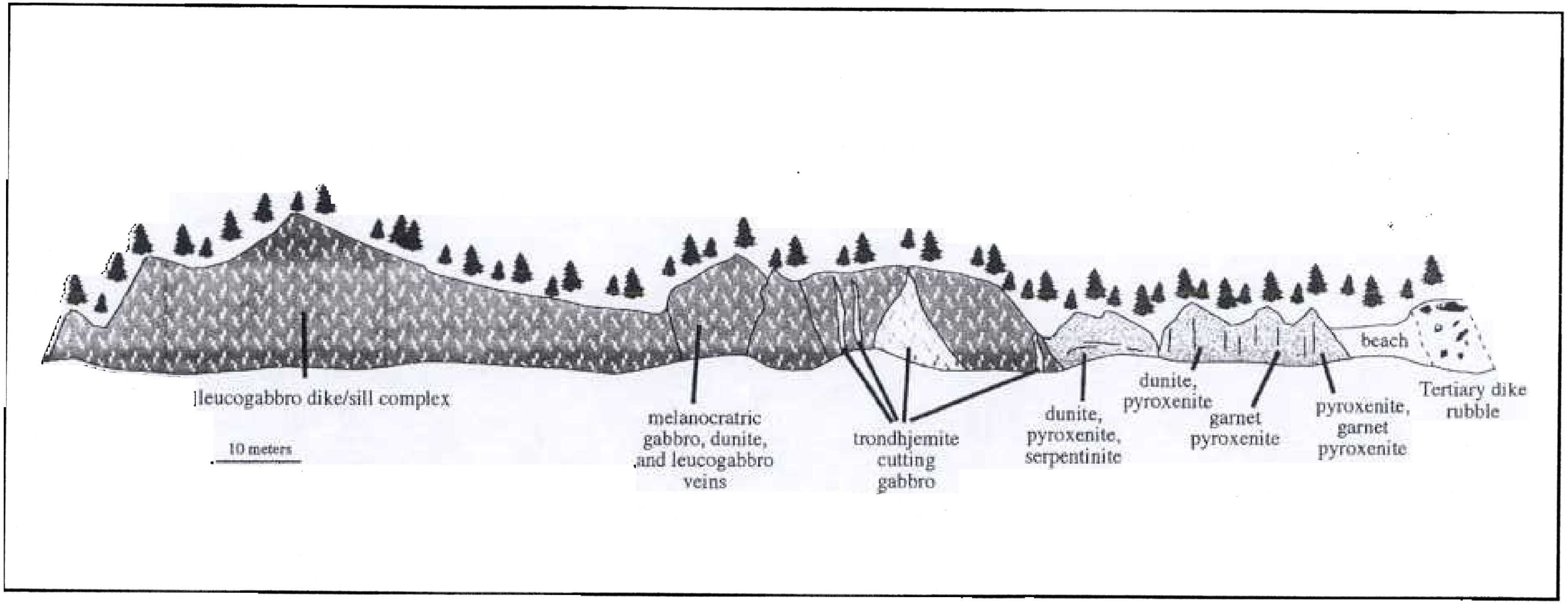


Figure 6. Halibut Cove mafic/ultramafic complex (~230 Ma, Middle Triassic), view to the northeast.

Figure 7A. Folded Triassic chert of the McHugh Complex on Cohen Island.

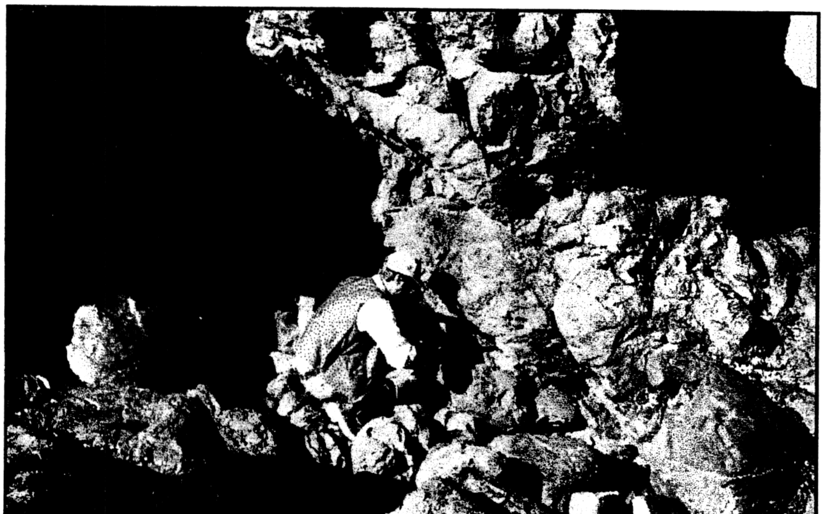


Figure 7B. Overturned depositional contact, Early Jurassic (Hettangian) chert overlying pillow basalt of the McHugh Complex on small island between Yukon and Hesketh Islands.

Figure 7C. Vertical depositional contact, Middle Triassic (Ladinian) chert overlying pillow basalt of the McHugh Complex, at Stop 3 on Hesketh Island.

Figure 7D. Limestone block in melange of the McHugh Complex. Where dated, these blocks are Permian and contain conodonts and fusilinids of tropical, Tethyan affinity. Such limestones could represent the decapitated tops of seamounts.

STOP 3—Southwestern point of Hesketh Island. Bedded radiolarian chert depositionally overlies pillow basalt (fig. 7C). The contact is vertical. Here the basal chert has yielded radiolarians of Middle Triassic (Ladinian) age, (C. Blome, written commun., 1994). Several other depositional contacts of chert over pillow basalt can be seen in Kachemak Bay, for example, on the small island between Yukon and Hesketh Islands, and at the end of MacDonald Spit. The age of the lowest chert varies from place to place, ranging from as old as Ladinian to as young as Albian-Aptian.

This belt of chert and basalt forms an internally complex but mappable tract within the McHugh Complex extending about 50 km along strike northeast from Seldovia village. During the initial craze of terrane analysis (Coney and others, 1980), this belt of chert and basalt was assigned to the so-called "Kachemak Terrane". We now realize that it is simply one of many chert- and basalt-dominated fault slices within the McHugh Complex. Status as a separate terrane would only be merited if one were prepared to also designate the dozens of other chert-basalt tracts in the McHugh Complex as separate terranes. What, then, would be the lower size limit? One kilometer? Ten meters? Hand-sample size?

STOP 4—Jakolof Bay. Nice exposures of a thick graywacke succession within the McHugh Complex extend from opposite the boat launch to well beyond the point to the northwest. The graywacke is many tens of meters thick. Bedding within it is revealed by conglomeratic horizons (a rarity in most graywacke bodies in the McHugh Complex); it dips about 45° to the north and is upright.

Low islands farther southeast in Jakolof Bay are underlain by a distinctive gray siltstone unit characterized by coherent strata with very gentle bedding dips and a strong slaty cleavage that nearly parallels bedding. At the 1:250,000 scale of the Seldovia quadrangle geologic map, this unit is too small to show separately, and so is included with the graywacke and conglomerate unit of the McHugh Complex (Bradley and others, 1999). Its age is unknown. Its style of deformation differs from other parts of the McHugh Complex; it might represent a slope basin accumulation that postdates mélange formation, or it may represent a thrust flat situated below imbricate horses visible higher on the slopes.

STOP 5—Barabara Point. Miocene Tyonek Formation (Kenai Group) overlying the McHugh Complex. Bluffs of weakly consolidated sandstone and conglomerate extend about 4 km from the mouth of Barabara Creek toward the southwest. Plant fossils from four localities here are of early to middle Miocene age; on this basis, the strata have been assigned to the Tyonek Formation (Magoon and others, 1976). At the southwest end of this exposure, the Tyonek Formation overlies greenstone of the McHugh Complex along a high-relief, profound unconformity. The presence of conglomerate clasts of McHugh Complex suggests that the Tyonek Formation here was derived from the ancestral Kenai Mountains.

Tertiary sandstone and conglomerate also crop out along Barabara Creek, 1-2 km southeast of the mouth of the creek near Barabara Point, near the bridge on the road connecting Seldovia and Jakolof Bay. These rocks lie topographically below nearby exposures of McHugh Complex, suggesting that they fill the paleo-valley of an ancestral Barabara Creek.

Other, smaller exposures of Tertiary sandstone and conglomerate have been mapped along the coast southwest of Seldovia. The ruins of a Russian-era (1850's) coal mine can be seen at Coal Cove, at the northern entry to Port Graham. According to Martin and others (1915, p. 108), American operators who briefly reopened the mine around the turn of the century found old rusted leg-irons, suggesting that convict labor had been employed! (The mine entry is now below sea level, a result of subsidence during the great 1964 earthquake).

En route to the next stop, we will pass outcrops of the Seldovia metamorphic complex and McHugh Complex. We will be returning on foot to this area for Stops 8-10.

STOP 6—VABM Atlas. Talkeetna Formation. This brief stop will give us a glimpse of the Jurassic Talkeetna Formation. Exposed here is a ~3-meter contorted layer of coal (said to be the only Jurassic coal in Alaska; G. Stricker, oral communication, 1989), overlain by micritic limestone, which in turn is overlain by pelecypod-bearing sandstone and conglomerate.

STOP 7—Border Ranges fault. The Border Ranges fault forms the boundary between the Peninsular and Chugach-Prince William terranes. Here on the west shore of Seldovia Bay, the fault is drawn through a gap in outcrop at the southeastern boundary of volcaniclastic strata assigned to the Talkeetna Formation. A narrow band of McHugh Complex mélange lies immediately to the south of this beach, beyond which are patchy outcrops of the Seldovia metamorphic complex. The Border Ranges fault originated as a subduction thrust. However, the field relations here preclude the possibility that the present fault is merely a thrust that has been steepened to near vertical. For it to be a thrust, essentially unmetamorphosed, supracrustal rocks of the Peninsular terrane in the hangingwall would somehow need to have been emplaced *above* deep-crustal blueschists in the footwall. It seems more likely that the fault that now bounds the Peninsular terrane on the southeast is a late-stage strike-slip or oblique-slip fault, as is indicated by subhorizontal slickenlines in the fault zone a few kilometers south of this location (Haeussler, unpublished field observations, 1992).

PART 2. SELDOVIA VILLAGE

Once we reach Seldovia and leave our things at the hotel, we will walk to Outside Beach by way of the road to Jakolof Bay. At the turnoff onto the side road to Outside Beach, we will pass a quarry of basalt and Middle Triassic (Ladinian) radiolarian chert.

STOP 8A. Outside Beach, North End. Outcrops along the beach north of the parking area and picnic grounds are of the McHugh Complex. Immediately below a memorial bench overlooking the ocean are exposures, from south to north of (1) graywacke blocks in argillite matrix; (2) basalt; and (3) radiolarian chert. About 300 m north along the beach, a prominent seastack exposes an argillite-matrix mélange containing blocks of greenstone, limestone, pebbly graywacke, and chert. This particular limestone is undated but is typical of the limestone blocks in the McHugh Complex (fig. 7D) that have yielded Permian fossils of Tethyan affinity. Still farther north, at the beginning of a long section of cliffs that continues to the end of the beach, is a belt of mélange containing certain blocks of sandstone and pebbly sandstone that are reminiscent of the Valdez Group (moderately sorted, dominant quartz and feldspar framework grains), and quite different from typical sandstones of the McHugh Complex (poorly sorted, matrix-rich, dominant chert and volcanic framework grains). This resemblance suggests the untested speculation that these blocks and their matrix might have been injected upward along a fault zone from underthrust Valdez Group.

STOP 8B, Outside Beach, South End. High-pressure metamorphic rocks of the Seldovia metamorphic complex stretch from the picnic area at Outside Beach to Watch Point in Seldovia, a linear distance of about 1.5 km. A variety of metamorphic rocks are exposed, including metabasite (metamorphosed basalt and allied volcaniclastic rocks), schist (metamorphosed pelite), thin-bedded quartzite (metachert), and marble. Various types of schists include common biotite-amphibole schist, epidote-chlorite-albite schist, crossite-epidote-chlorite blueschist, and blue-green amphibole-garnet-epidote schist. The various packages of metamorphic rocks are typically separated by steep faults; there are differences in metamorphic grade between these packages. All mafic rocks in these packages preserve evidence of high-pressure metamorphism, as they contain either blue amphibole (typically crossite) or barroisite, a sodic-rich calcic amphibole which forms at moderate to high pressures and temperatures higher than blueschist facies. Throughout the Seldovia metamorphic terrane you will notice superb early intrafolial folds, later tight to isoclinal folds, strong mineral and intersection lineations, kink bands, and late sulfide-rich shear zones, and even later brittle fault zones. Amphibole and white-mica separates from two schist samples have yielded $^{40}Ar/^{39}Ar$ plateau ages of 191-192 Ma (fig. 8) This age falls in the Early Jurassic (Pliensbachian according to the DNAG time scale) and, as noted previously, is believed to date an episode of subduction-zone metamorphism. These rocks are correlative with high-pressure rocks exposed on Kodiak Island (Roeske and others, 1989).

Between the picnic area and the marble quarry (visible on the point to the southwest) there is an interesting wave-washed outcrop best viewed at low-tide, and during calm-water conditions. At this outcrop (NO HAMMERS HERE PLEASE) the fragmental nature of one of the distinctive units in the blueschist terrane can be observed, and its origin debated. The rocks are strongly foliated and the protolith is questionable. In some places, the fragments resemble volcaniclastic conglomerate clasts (or perhaps pillow breccia), whereas in other places the apparently fragmental nature of the outcrop can be ascribed to dismemberment of isoclinal folds. There are some obvious fold hinges here, but are these folded clasts or are they clues that the whole sequence is transposed? We favor an origin by early isoclinal folding of a volcaniclastic conglomerate/ sandstone unit, similar to units in the McHugh Complex, and in less-deformed parts of the Seldovia metamorphic terrane. Excellent examples of less-deformed volcaniclastic conglomerate can be observed in coastal exposures north of Watch Point.

Blue amphibole is visible in a small outcrop near the outlet of Trena Lake on its east side. The block highest on the beach is most "visibly blue". The fine color lamination in this outcrop is due to variations in concentration of blue amphibole, epidote, and chlorite.

Stop 9—Marble Quarry. The old marble quarry is unfortunately mostly filled in, but numerous blocks and a few outcrops showing interesting structures and minerals remain. There are bright green (fuchsitic?) micas, chloritized garnets with beautiful pressure shadows, and infolded graphitic (carbonaceous) schist and layers of amphibolite still visible. The foliation in the metapelite and metabasite layers is clearly folded, whereas the marble shows evidence for grain-scale recrystallization and polyphase folding. A late stylolitic cleavage truncates both F1 and F2 folds.

Stop 11—Gray Cliff. Further southwest at Gray Cliff, marble and dolostone are interlayered, and are in fault contact with adjacent metabasite and interlayered quartzites (recrystallized chert?). Just south of Gray Cliff, beautiful quartz-garnet-mica schists display tight to isoclinal folds, and are cut by late brittle faults.

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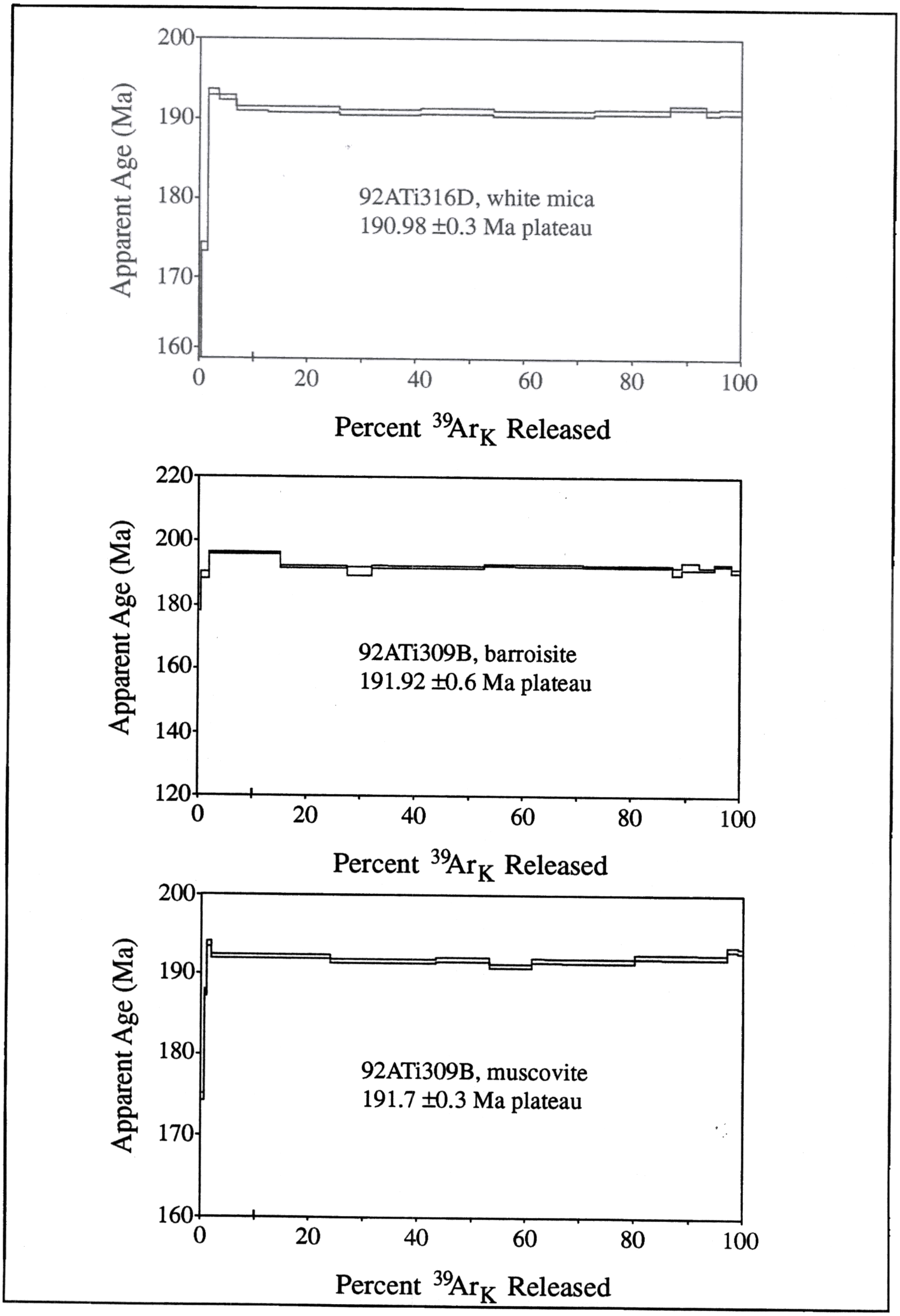

Figure 8. ^{40}Ar / ^{39}Ar release spectra for metamorphic rocks of the Seldovia metamorphic complex. For all three mineral separates, calculated isochron ages are nearly identical to the plateau ages shown here.

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