GRAPHIC 1
ENVIRONMENTAL GEOLOGY
III. A. 1. Geology

A. Physical Characteristics

1. Geology: This section focuses primarily on the issues of tectonics and associated potential seismic and volcanic hazards, and the bottom sediment conditions of lower Cook Inlet.

a. Physiography: Cook Inlet is a tidal estuary which trends northeast-southwest and flows into the Gulf of Alaska east of the base of the Alaska Peninsula. The inlet is approximately 200 nautical miles long and 75 nautical miles wide at the mouth. Knik Arm and Turnagain Arm are situated at the head of the inlet and are 45 and 43 miles long, respectively (graphic 1).

Cook Inlet is bordered on the west and northwest by the Aleutian Range and the Alaska Range; the Talkeetna Mountains lie to the northeast; and the Chugach and Kenai Mountains lie to the east and southeast. Glaciers are very common throughout these mountains; the tributary streams are heavily laden with glacial silt and contribute a heavy sediment load to upper Cook Inlet. Much of the fresh water flowing into the upper inlet is from the Susitna River and the Knik Arm, as well as from major tributaries, small rivers, and creeks. The Kenai lowlands, which are adjacent to the upper inlet, extend for more than 60 miles east to the Kenai Mountains. Along the southern margins of Cook Inlet, the mountains rise directly from the water. Five active volcanos border the inlet on the west side: Mount Spurr, Redoubt, Iliamna, Augustine, and Mount Douglas (graphic 1). These volcanos define a belt of volcanic activity which is contiguous with the arcuate zone of volcanoes trending southwest through the Katmai District and into the Aleutian Archipelago.

Shelikof Strait is located between the west side of Kodiak Island and the Alaska Peninsula. Shelikof Strait extends about 140 miles from the area between the Barren Islands and Cape Douglas to the southwestern corner of Kodiak Island. Shelikof Strait is about 30 miles wide. Shelikof Strait is bordered on the west by the Katmai National Monument mountains and glaciers and on the east by the rocky coastline and many bays of Afognak and Kodiak Islands. In the Katmai area west of Shelikof Strait, seismic activity has been identified by Pulpan and Kienle (1979).

b. Tectonics: This section is included to provide a general overview of the geologic conditions necessary for the occurrence of potential geologic hazards as described in sections III.A.3 and III.A.4. The lower Cook Inlet/Shelikof Strait region is part of a belt of Mesozoic and Tertiary sedimentary rocks--the Matanuska-Wrangell Basin--that extends northeast into the upper Cook Inlet and southwest down the Alaska Peninsula and Shelikof Strait (fig. III.A.1.b.-1 and graphic 1). The Mesozoic rocks along this belt, primarily of marine origin, can be greater then 6100 meters (20,000 ft) thick, and the continental Tertiary strata can be as deep as 7600 meters (24,000 ft) (Magoon, et al., 1976).

The tectonics of the eastern Aleutian arc are dominated by the interaction between the North American and Pacific plates (fig. III.A.1.b.-1). Along the Queen Charlotte-Fairweather faults, the two plates are slipping past one another along a right lateral transform fault system. Along the Aleutian Island arc and the Aleutian-Alaska Range, up to Mt. McKinley, the oceanic Pacific plate is underthrusting the continental North American plate. The Aleutian trench axis marks the initial downbending of the oceanic plate, and the active volcanic arc approximately traces the 100 kilometer depth contour of the subducted plate. The transition zone between these two distinct tectonic regimes lies between the Denali fault and the Gulf of Alaska and contains a complicated system of thrust and strike slip faults.

In the Cook Inlet/Shelikof Strait region, three major fault systems have been mapped: the Castle Mountain fault, the Bruin Bay fault, and the Border Ranges fault (figs. III.A.1.b.-2 and III.A.1.b.-3). In addition, a major unnamed thrust fault separates the Mesozoic and the Cenozoic in southern Kodiak. The trace of the Castle Mountain fault cuts the grain of the arc system at an oblique angle of 20 degrees and transects the volcano line just south of Mt. Spurr volcano. The relative motion along this fault is right lateral strike slip. Fairly recent displacements have occurred along the Castle Mountain fault as indicated by offset Pleistocene glacial deposits and lineations (Evans, et al., 1972). Both the Bruin Bay and the Border Ranges faults are thrusts that follow essentially the trend of the arc structure. However, neither of these faults shows any evidence of recent displacement: the Border Ranges fault has been inactive since late Mesozoic-early Tertiary time and the Bruin Bay fault is not offsetting any strata younger than 25 million years (Magoon, et al., 1976).

With regard to the offshore areas, seismic reflection surveys indicate little recent surface faulting in the lower Cook Inlet (Magoon, et al., 1979). A few small faults have been observed north of the Augustine-Seldovia arch. Normal faults associated with horst and graben tectonics are common near Augustine Island (fig. III.A.1.b.-2). Potential surface faulting of the seafloor is indicated in Shelikof Strait between Cape Douglas and Shuyak Island (Magoon, et al., 1979).

Two well-defined aftershock zones dominate the historic seismicity of the eastern Aleutian arc. One is associated with the 1957 Andreanof-Fox Islands event, magnitude 8.2 (fig. III.A.1.b.-4, bottom). Sykes (1971) did not identify the area between these two zones as a seismic gap because he considered the possibility that most of it ruptured during an 8.7 event which occurred in 1938. The aftershock zone of this event is rather poorly defined but is frequently delineated as indicated in figure III.A.1.b.-4 (bottom). The gap between the western boundary of the 1938 event and the eastern boundary of the 1957 aftershock zone is called the Shumagin gap. This gap to the southwestern margin of the 1964 aftershock zone is experiencing a period of relative quiescence. This quiescence is indicated by the historic seismicity (fig. III.A.1.b.-4, top), and by Pulpan and Kienle (1979) who show a definite change in the level of seismicity along a line that transects the arc close to the southwestern margin of the 1964 aftershock zone. This line also coincides with pronounced geologic changes on the Alaska Peninsula near Wide Bay (Burk, 1965). The fact that this line is nearly congruent with a major seaward offset of the volcano line lends further support to the notion that a transarc boundary exists near the eastern edge of Kodiak Island. Archambeau (1979) computed the stress drop for recent earthquakes in the Aleutian-Alaska arc system and found high stress levels from Kodiak Island to the end of the Alaska Peninsula.

Along convergent plate boundaries most of the seismic energy is released during great (magnitude 7.8) earthquakes (Kanamori, 1977). The aftershock zones of these great earthquakes do not overlap, which suggests that the areas left between them, so called seismic gaps, are the most likely sites for the next great earthquake. The longer the time interval since the occurrence of the last great earthquake in a given gap the higher is the probability for a next great earthquake. Unfortunately, the recurrence rate of great earthquakes is poorly known. Estimates range from a maximum of 800 years, based on geological evidence (Plafker, 1971), to a minimum of 33 years, based on seismic patterns over the past 80 years (Sykes, 1971). In Alaska, there is the additional problem that aftershock zones of great earthquakes before 1964 are poorly defined.

In spite of these shortcomings, the seismic gap concept is useful for determining the likelihood of the occurrence of the next great earthquake. It is noteworthy that the only earthquakes above magnitude 7 that occurred in Alaska in the past years were located within the two gaps identified by Sykes (1971). These two events were the 1972 magnitude 7.6 earthquake near Sitka, and the February 1979 magnitude 7.7 earthquake near Mt. St. Elias (Lahr, et al., 1979).

c. Potential Hazards Associated with Seismic Activity: The Cook Inlet/Shelikof Strait region is susceptible to earthquakes of magnitude 6.0 - 8.8 (seismic risk zone 3). Major structural damage can result from earthquakes of these magnitudes. Damage can be caused either directly by ground shaking, fault displacement, and surface warping, or indirectly by seismic sea waves (tsunamis), ground failure, and consolidation of sediments.

Ground Shaking: Damage from ground shaking is likely to be greatest in areas underlain by thick accumulations of saturated, unconsolidated sediments rather than in areas underlain by solid bedrock. This is especially true if the frequency of seismic waves is equal to the resonant frequency of the sediment. Moreover, ground shaking can weaken sediments and trigger other hazardous events, such as landsliding and ground fissuring.

Within the Cook Inlet area, Anchorage and Homer experienced significant damage directly due to ground shaking during the 1964 earthquake (National Academy of Sciences, 1972), but shaking generally was subordinate to other seismic effects in terms of property damage. The potential of shaking as a danger to structures, such as drilling platforms within the inlet, is uncertain. Page, et al., (1972) have presented data which relate ground motion in terms of accelerations, velocities, displacement, and duration of shaking with earthquake magnitude. These data show that ground motion parameters decay exponentially away from the epicenter of an earthquake.

Surface Faulting: The distribution of active surface faults within the lower Cook Inlet has recently been mapped by Pulpan and Kienle (1979) and Bouma and Hampton (1979) (fig. III.A.1.b.-2). Recent activity evidently has occurred on the Castle Mountain fault, a short distance northwest of Cook Inlet (Evans, et al., 1972). After the 1964 earthquake, Foster and Karlstrom (1967) mapped an extensive zone of ground fissures adjacent to the southeast margin of Cook Inlet extending from Kasilof to Chickaloon Bay. They suggested that the zone might be underlain by an active fault. If this speculation is correct, the fault could extend into lower Cook Inlet.

Surface Warping: Abrupt tectonic deformation accompanies most large earthquakes. For example, the 1964 earthquake caused a landward tilting of the continental margin. This involved an offshore zone of uplift which extended at least to the outer edge of the continental shelf, and a shoreward zone of subsidence which extended onto the mainland. Maximum uplift was about 15 meters (Malloy and Merrill, 1972), and maximum subsidence was about 2.5 meters (Plafker, 1969), indicating the probable magnitude of vertical displacement that could accompany a major quake.

Most of the Cook Inlet experienced tectonic subsidence of less than 1/3 meter in the 1964 quake, but an area extending from Kamishak Bay to near the mouth of Drift River is believed to have been slightly uplifted, less than 2/3 meter (Plafker, 1969).

Tsunamis: Seismic sea waves (tsunamis) are generated when much sea water is displaced, either by tectonic displacement of the sea floor (regional tsunamis) or by large rockfalls or landslides (local tsunamis). Regional tsunamis occur as a train of long-period waves that radiate energy in a pattern that is controlled by the geometry of the source disturbance. For example, deformation in 1964 hinged around an axis which trended northeast from Kodiak Island to northern Prince William Sound. The most intense radiation of the tsunami's energy was perpendicular to this axis (Pararas-Carayannis, 1967). The result was extensive damage to the subsided, seaward-facing coastal areas of Kodiak Island and the Kenai Peninsula (Plafker, 1969). Maximum runup from this tsunami was about 60 feet above mean lower low water, at Narrow Cape, Kodiak Island (Berg, et al., 1971). The Kodiak Islands shielded much of the southeast facing coast of the Alaskan Peninsula from serious inundation from the tsunami (Spaeth and Berkman, 1972).

Tsunamis do not occur with every submarine earthquake, and their prediction is not yet certain. They are seldom detectable in the open ocean but build up to significant, destructive heights close to and along the shoreline.

The degree of damage by tsunamis is partly controlled by the level of the tide. The 1964 earthquake occurred near the time of low tide, and consequently runup from the first tsunami wave did not extend above normal high tide at some places. The potential occurrence of a tsunami remains for several hours after the main shock, however, destruction might be delayed until the next high tide. For example, the town of Cordova was hit by a 7-meter wave at high tide, approximately 7 hours after the main 1964 earthquake.

The narrow, elongated geometry of the Cook Inlet reduces the chances that a tsunami generated outside the inlet will propagate significant destructive energy into it. The tsunami generated by the 1964 earthquake produced damage in the lower Cook Inlet area at Rocky Bay and Seldovia. It hit most of the west coast of the lower Cook Inlet, but caused no damage. If a regional tsunami should be generated within the inlet, it probably would have little effect in open waters, but could produce significant damage along parts of the coastline.

Local tsunamis are likely to occur along steep, indented coastlines, such as exist along some parts of the lower Cook Inlet, when unstable rock masses are shaken loose from steep slopes or when submarine landslides occur on unconsolidated alluvial deltas. They are a particularly dangerous seismic hazard because they strike without warning, during, or shortly after, an earthquake. Most damage by locally generated waves usually is confined to the embayments within which they originate. Kienle and Forbes (1976) have described the effects of a tsunami generated by the 1883 eruption of Augustine volcano. This tsunami reached English Bay and Port Graham in 25 minutes and attained a height of 10-12 meters.

Local tsunamis can be exceptionally large; a surge wave ran 530 meters (vertically) up the slopes of Lituya Bay in the eastern Gulf of Alaska during the 1958 southeastern Alaska earthquake. Local tsunamis accounted for more loss of life than any other factor in the 1964 earthquake.

Ground Failure: Various types of ground failure, both on land and underwater, are a major cause of destruction associated with large earthquakes, especially in areas underlain by thick, unconsolidated sediments. The many deltas that occur along the Alaskan coastline are appealing sites for construction because they commonly are the only extensive flat ground along the coast. But, many of these deltas are especially prone to earthquake-induced liquefaction and sliding because of their loose, water-saturated, sandy nature. The disastrous sliding and resulting waves at Valdez in 1964, which caused extensive damage and loss of life, is an example (Coulter and Migliaccio, 1969). Local slides also occurred at Homer, Seward, and Whittier in 1964.

Underwater dispersal of slide sediments also poses a problem. The sediment can travel a few miles from the origin of the slide, perhaps as a turbidity current, and cause burial or physical damage to structures on the sea floor. Burial and breaking of submarine cables has been reported for slides at Valdez (Coulter and Migliaccio, 1969) and for many large-scale, deep-water submarine slope failures (e.g., Heezen and Ewing, 1952; Menard, 1964).

Translatory block sliding occurred at Anchorage in 1964 and caused most of the damage there. Failure generally took place in the Bootlegger Cove Clay, a Pleistocene deposit up to 75 meters thick that underlies much of Anchorage (Hansen, 1965, Miller and Debrovolny, 1959). The clay unit was weakened and failed under seismic stresses, causing the overlying material to slide downslope as large translatory blocks. Some landsliding in Anchorage is also believed to have resulted from liquefaction of sand layers within the Bootlegger Cove Clay.

Ground fissures and associated sand extrusions occurred extensively in the Cook Inlet area in 1964 (Foster and Karlstrom, 1967). As noted previously, a large zone of fissures, 95 kilometers long and 10 kilometers wide, developed between Kasilof and Chickaloon Bay. Fissures developed mainly in unconsolidated sediments and were as much as 10 meters across and 8 meters deep. They split several trees that straddled them. Only a few avalanches and slumps were noted along the onshore coastal areas of Cook Inlet.

Sharma and Burrell (1970) and Bouma and Hampton (1976) have shown a facies change in bottom sediments in lower Cook Inlet from gravel - boulder size sediment with minor amounts of sand, north of a line between Chinitna Point and a point 5-7 km southwest of Anchor Point, to predominantly sand size material with varying amounts of shell debris south of this line in lower Cook Inlet. Wennekens (1976) and Bouma and Hampton (1976) have described dark grey-black silts and clays in inner Kachemak Bay, particularly in the area where the G.F. Ferris had been stuck. Sediments similar to these have not been found in the lower Cook lease area in studies by Bouma and Hampton (1979).

Consolidation: Ground subsidence resulting from consolidation and/or lateral spreading of sediments, without actual sliding, is another expectable seismic hazard. This heightens the likelihood of extensive flooding along coastal areas and, of course, could possibly cause submergence of affected marine installations. Consolidation subsidence of up to 1¼ meters (4.6 ft.) occurred on Homer spit in 1964 and contributed to the closing of port facilities there.

d. Volcanoes: Calc-alkaline volcanism along the Aleutian arc is the result of plate convergence between the North American and Pacific plates (fig. III.A.1.b.-1). Nineteen volcanoes form the eastern Aleutian arc from the Upper Alaska Peninsula to Cook Inlet. Of these, eight have erupted in this century and another six have active fumarole fields. The 1912 Katmai eruption was one of the largest eruptions in the world in this century. So far, only two of the most active Cook Inlet volcanoes, Augustine and Redoubt have been studied by Pulpan and Kienle (1979).

Augustine Volcano: A reasonable understanding of the nature of Augustine consists of 1) its eruptive history, 2) its geology and geochemistry, 3) its internal structure, 4) its recent (past 9 years) seismicity and 5) the major eruptive cycle which occurred 3 years ago.

1) Augustine's eruptions are typically Pelean, charcterized by moderate to violent ejection of solid or very viscous hot fragments of new lava, the ejecta being typically glassy to lithic blocks, ash and pumice, glowing avalanche activity and extrusion of domes or short, very thick flows (MacDonald, 1972). Since its discovery and naming by Captain Cook in 1778, Augustine has erupted five times (1812, 1883, 1935, 1963/64, 1976) with response times between eruptions as short as 12 years and as long as 71 years. The volumes of uncondensed ejecta has been 0.1 cubic kilometers for the 1963/64 eruption (Detterman, 1968) and 0.1 to 0.2 cubic kilometers for the 1976 eruption (Johnston, 1978; Kienle and Shaw, 1979). These data indicate that the feeding magma chamber is relatively small. In contrast, the volume of the 1912 Mt. Katmai eruption for example is about 2 orders of magnitude greater than that for typical Augustine eruptions.

2) Augustine is a calc-alkaline stratovolcano that erupts predominantly andesitic and dacitic magma (Kienle and Forbes, 1976; Johnston, 1978). The basement is sedimentary; Jurassic and Cretaceous sandstones and shales have been uplifted on the southern flank of the volcano where they crop out (Buffler, 1975).

3) Pearson (1977), Pearson and Kienle (1978) and Lalla (1979) have determined the shallow seismic velocity structure of the volcano. The little more than 1000 meters high cone consists of a central andesitic-dacitic dome complex (V_p = 2.3 to 2.6 km/sec) that is mantled by very low velocity (1.2 km/sec) pyroclastic debris flow and pumice flow material on the lower flanks. Zeolitized high velocity (5.1 km/sec) sediments underlie the volcano at a depth of 0.9 kilometers below sea level and the sediments from 0- to 900-meter depths have intermediate velocities of 2.6 to 3.4 kilometers/second. The volcano may have a small (less than 200 m) higher P-velocity (4.4 km/sec) conduit.

4) The shallow seismicity observed over the past 9 years at Augustine has been classified by Lalla (1979) into 2 categories, both of swarm type: 1) Surface activity correlating strongly with below-freezing temperatures and probably originating in pockets of the winter ice pack near the shoreline of the volcano and 2) volcanogenic earthquakes from depths shallower than 6 kilometers. Most of the type 2 shallow seismicity originates in a very shallow (0 to 1 km deep) postulated hydrothermal system that overlies an inferred shallow (less than 6 km deep) magma chamber. So far we have observed 2 periods of intense shallow earthquake swarm activity, the first in 1970/1971, and the second prior to the 1976 eruption (Lalla, 1979; Kienle and Forbes, 1976). While the first swarm was not followed by a major eruption (even though we have one report from Kamishak Bay fishermen of a minor ash eruption on October 7, 1971), the second swarm period from May 1975 to January 1976 was followed by the 1976 eruptions. Following the eruptions the volcano has again been seismically quiet.

5) The 1976 eruption has been summarized by Kienle and Forbes (1976), Johnston (1978) and Kienle and Shaw (1979). The eruption followed a similar pattern as previous historic eruptions, starting with a set of powerful vent clearing explosions that were accompanied by strong glowing avalanche activity between January 22 and 25, 1976; 13 major eruptions were detected in January on seismic and infrasonic arrays. The average thermal energy per eruption was about 10^{14} to 10^{15} Joules. Several of the eruptions penetrated into the stratosphere and optical effects were observed for five months following the eruptions at Mauna Loa, Hawaii. Glowing clouds and avalanches descended all slopes of the volcano with velocities of order 50 meters/second (Stith, et al., 1977) and temperatures between 600 and 650°C (Kienle and Lalla, unpublished data).

Several of the glowing clouds detached themselves from the debris avalanches, which were originally directed north through a breach in the summit crater, but then veered toward the east. After 12 days of quiescence, Augustine erupted again culminating with the extrusion of a hot (about 600 to 800°C) viscous andesitic-dacitic lava dome. This phase was accompanied by pyroclastic avalanche activity but of a different type, the feeding mechanism not being column collapse or directed blasts as in January, but dome collapse. Renewed dome growth occurred in April 1976, after which the eruptions ended.

The principal potential hazards of Augustine Island are glowing avalanches (pyroclastic flows), mudflows and floods, minor lava flows, bomb and ash falls, noxious fumes, poisonous gases and acid rains, and tsunamis. Of these the most serious potential hazard to offshore oil and gas development are glowing avalanches. Ballistic studies indicate that the ejection range of large bombs is mainly restricted to the island itself. Ash from the past eruption spread all over southern Alaska, as far north as Anchorage and Talkeetna, and as far east as Sitka, 1100 kilometers away. The ash dispersal is strongly dependent on the prevailing wind directions. Near the island, ash falls can be accompanied by heavy acid rains and large clouds of noxious fumes. It is clear that no place on the island is safe to erect permanent or semi-permanent structures. The 1883 eruption produced tsunamis that crossed the entire lower Cook Inlet.

Redoubt Volcano: Unlike Augustine Volcano, the much higher peak of Redoubt (10,197 ft) is covered by glaciers which adds hazards due to floods and massive mudflows. Flooding may pose a serious threat to the Drift River tanker terminal, which was constructed after the 1966 floods. During the January 1966 eruptions, excessive meltwater may have accumulated in the summit crater (1 x 1.6 km in size, at an elevation of 8,000 to 8,500 ft) and then drained catastrophically. The outburst of water and ice from the crater apparently caused the Drift River to break up in mid-winter. Two separate flash floods reached the mouth of the Drift River, the first of which carried large ice blocks. Another potential flood hazard arises from the fact that the glacier that descends from the summit crater due north, the North Glacier, could dam the Drift River. If an advance occurs, the river could get dammed creating a lake that could drain catastrophically. Little is known about the geology of Mt. Redoubt, which has never been mapped in detail. Historic eruptions occurred in 1778, 1819, 1902, 1933, and 1965-68 with eruption intervals ranging from 31 to 83 years.

e. Bottom Sediments: The distribution of bottom sediments in lower Cook Inlet has been described by Sharma and Burrell (1970) and Bouma and Hampton (1979). Graphic 1 shows the distribution of bottom sediments in lower Cook Inlet and Shelikof Strait. Studies by the U.S. Geological Survey on the environmental geology of Shelikof Strait have not been published at this time. The distribution of suspended and bottom sediments in Cook Inlet is controlled primarily by tidal currents, but also by seasonally varying fresh-water discharge into the inlet. Bottom sediments are supplied by rivers entering the inlet and by coastal erosion. Gravel material is carried into the inlet during river flooding, but some coarse bottom sediments are primarily sands with some shell debris.

Erosion and redistribution of bottom sediments is a potential hazard in the Cook Inlet, but enough data are available to pinpoint troublesome areas, (Bouma and Hampton, 1979). Bouma and Hampton (1979) have shown the presence of numerous fields of rippled sand bedforms in the lower Cook lease area (graphic 1). The presence of such large bedform features suggests a significant potential for bottom scouring and deposition in the lower Cook Inlet lease area. A variety of types and sizes of bedforms are found on the bottom of lower Cook Inlet. These bedforms fall into two major categories: transverse current features (current ripples, megaripples, and sand waves) and longitudinal current features (sand comets, sand ribbons, and sand ridges).

Bouma and Hampton (1979) suggest that at least a part of the lower Cook Inlet sand-wave field may contain relict features and that the hydrodynamic regime may have undergone some major changes since the retreat of the Holocene glaciers that once covered this area. Hampering understanding of these conditions is the lack of a Holocene chronology of geologic events which occurred in lower Cook Inlet.

Bouma and Hampton (1979) have concluded the following:

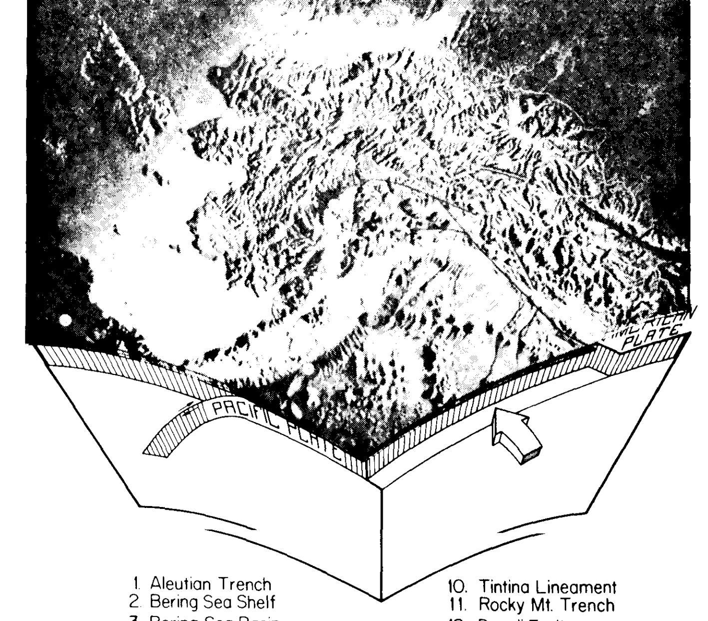
1. The lower Cook Inlet sand-wave field appears to have been quite stable for the last five years along the segments studied. No movements greater than 10 meters per year were detected.

2. A large number of the megaripple patterns and associations with the sand waves also showed no measurable changes.

3. Either the rates and modes of change of a vast majority of sand waves and megaripples are not readily detectable with the techniques and time period employed, or they respond to periodic catastrophic phenomena that did not occur during the 5-year study period. Possibly some of the lower Cook Inlet sand waves are relict.

4. Some of the nonchanging sand-wave associations are in areas where strong bottom currents appear to be active.

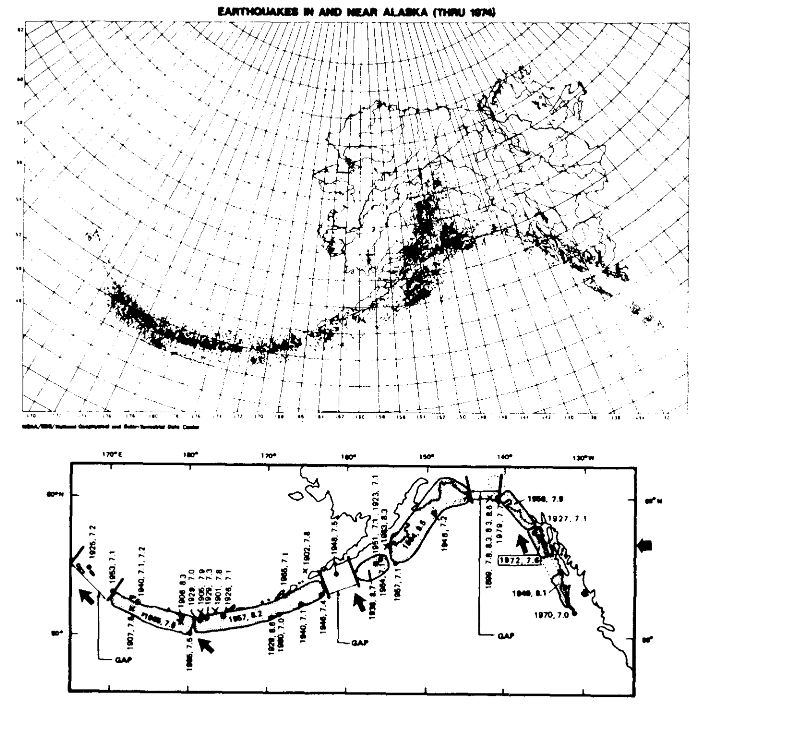
FIGURE III.A.1.b-1



1. Aleutian Trench
2. Bering Sea Shelf
3. Bering Sea Basin
4. Arctic Basin
5. Brooks Range
6. Alaska Range
7. Cook Inlet
8. Kodiak
9. Shumagin Islands
10. Tintina Lineament
11. Rocky Mt. Trench
12. Denali Fault
13. Fairweather Fault
14. Chugach–St. Elias Thrust
15. Chatham Strait Fault
16. Queen Charlotte Fault

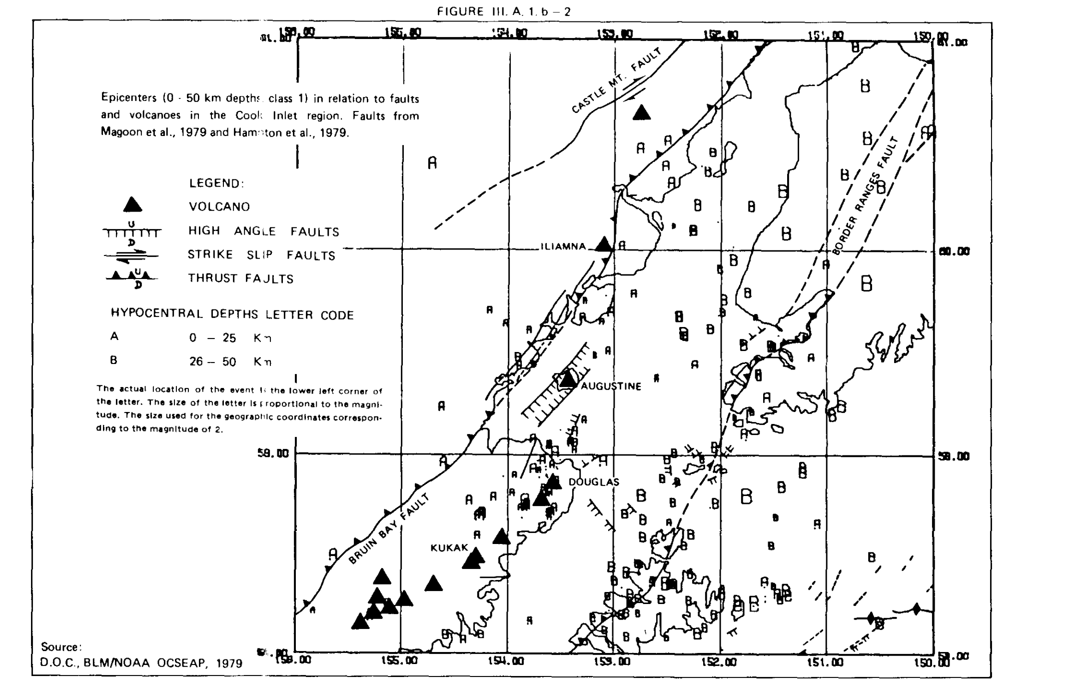
Plate convenence in southern Alaska.

FIGURE III.A.1.b-4



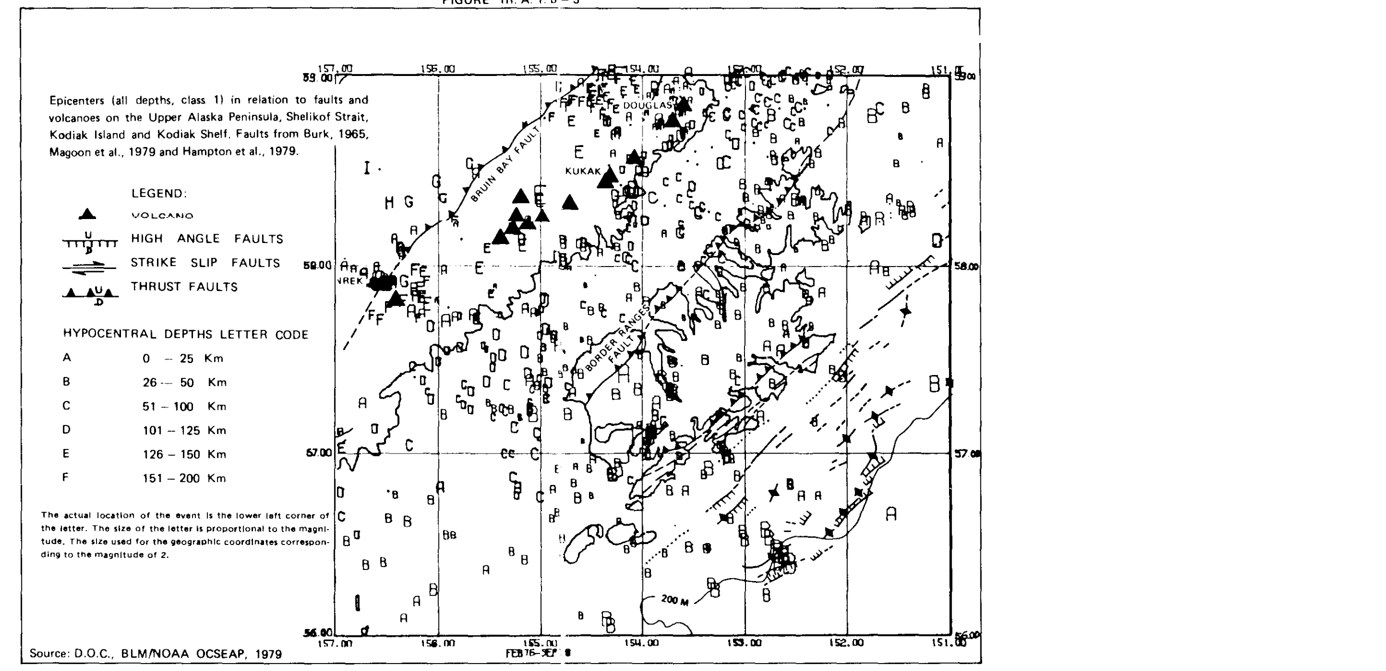
Historic seismicity (top, from NOAA/EDS) and aftershock zones of great earthquakes, modified from Sykes, 1971 (bottom). Other major Alaskan earthquakes are also shown.

FIGURE III.A.1.b-2



Source: D.O.C., BLM/NOAA OCSEAP, 1979

FIGURE III.A.1.b-3



Source: D.O.C., BLM/NOAA OCSEAP, 1979