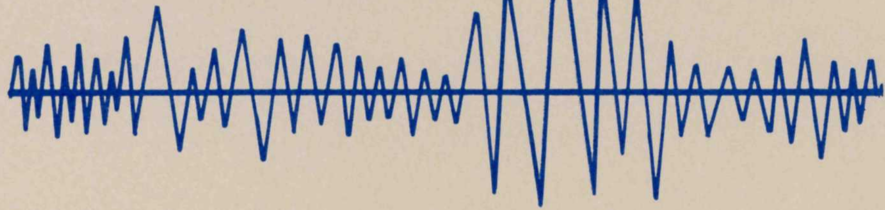
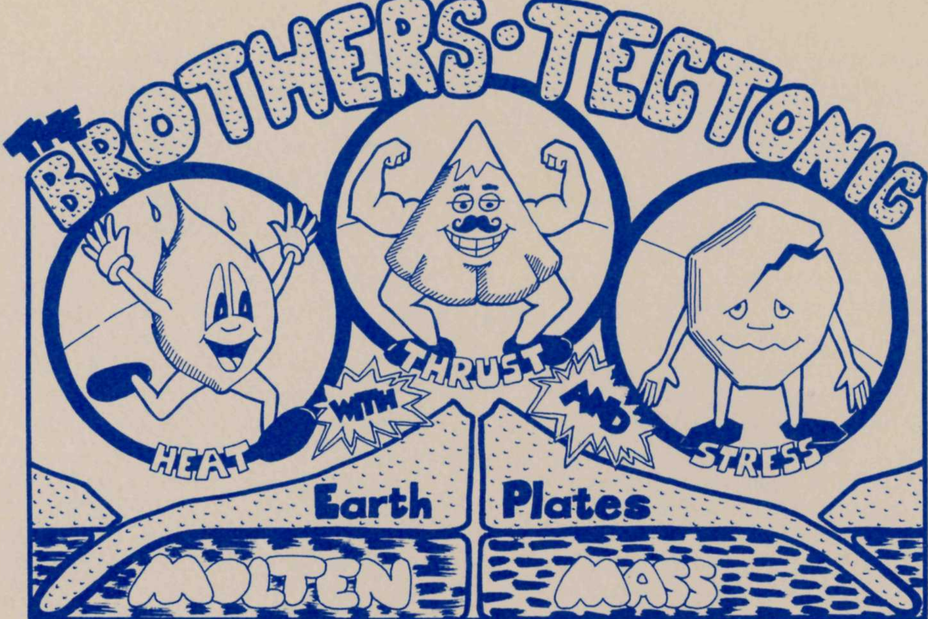
Environment Canada | Environnement Canada
Canadian Parks Service | Service canadien des parcs

ARE WE ON SOLID GROUND?



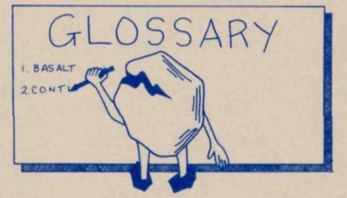
presented by...



THE GEOLOGY OF PACIFIC RIM NATIONAL PARK

Every so often in the progress of science a theory emerges that revolutionizes our beliefs about the world around us. **Plate tectonics** is such a theory. By providing a new concept of the earth's outer structure, it answers some puzzling geological questions on the cause of earthquakes, the movement of continents, and the formation of oceans. Our current knowledge of this story is illustrated with the assistance of the Brothers Tectonic, representing the forces of heat, thrust, and stress.

All the major features of plate tectonics can be found in the Pacific Northwest. Vancouver Island is caught in the middle of a dramatic encounter between the shifting plates of continent and ocean.



The Glossary explains terms shown in **bold type** throughout the pamphlet.

Basalt: a dark, fine-grained rock formed by the cooling of molten lava. Basalt rocks underlie most of the ocean basins.

Continental Slope: that part of the ocean floor that extends from the continental shelf to the deep sea floor, at a relatively steep angle. (fig. 6)

Crust: the hard outer shell of the earth. A crustal plate includes both the crust and upper mantle. (fig. 2)

Fault: a major fracture in the earth's crust where a block of rock has been displaced relative to another. (fig. 5)

Magma: molten rock in the crust and mantle. It's called lava when it flows onto the earth's surface, above or below water.

Mantle: a hot "plastic" layer of the earth that lies between the surface crust and the inner core. (fig. 2)

Plate Tectonics: theory that the earth's crust and upper mantle consists of large plates that are constantly moving. Plate motion results in volcanic eruptions, earthquakes, uplift of mountain ranges, and the creation of new ocean basins.

Radiolarian: a single-celled microscopic animal that first appeared in the oceans some 500 million years ago.

Subduction Zone: in plate tectonics, the area where one crustal plate slides under another. Subduction zones are sites of earthquake and volcanic activity. (fig. 3)

Terrane ***(teh-rain):*** a block of crust, bounded by faults, that has been moved from its place of origin by plate motion and added onto a continent.

Trench: a long, narrow, and deep depression of the sea floor where a subducting plate descends towards the mantle. Trenches are steep-sided, oriented parallel to the continent, and may be thousands of kilometres long. (fig. 3)

Volcanic Island Arc: a chain of islands that can form as a plate slides over a rising jet of magma. A deep trench lies on one side of the islands and an ocean basin on the other. The Hawaiian Islands are an example.

A Dynamic Theory. There was an ancient belief that the world was carried on the back of a giant tortoise whose movement caused earthquakes. Modern scientists have pieced together evidence that supports much the same idea! We now know that "the restless tortoise" is, in fact, eight huge crustal plates and several smaller ones that interlock to form a pattern remarkably similar to a tortoise's shell (fig. 1). The plates are thinnest (25 - 100 km) under the oceans and thickest (up to 150 km) under the continents — about as thick in proportion to the earth as an eggshell is to an egg.

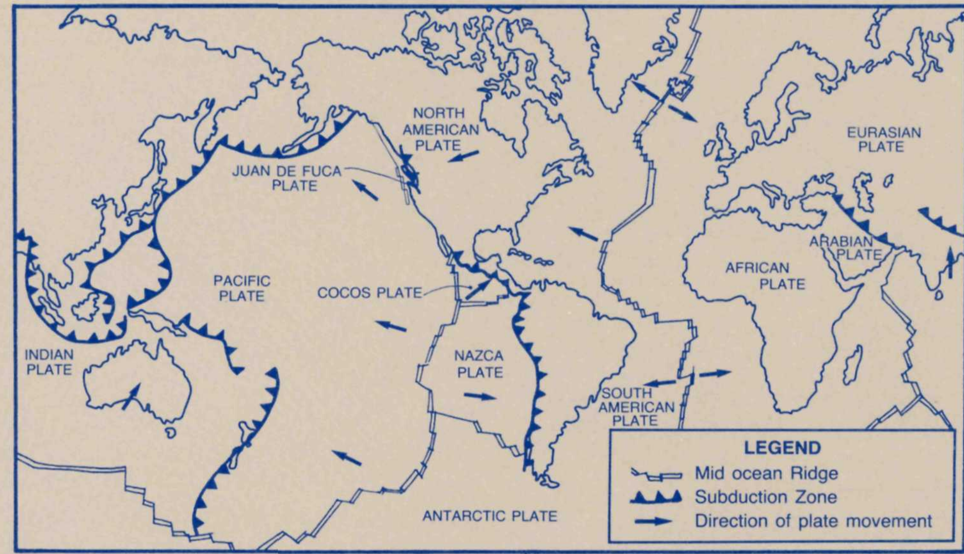
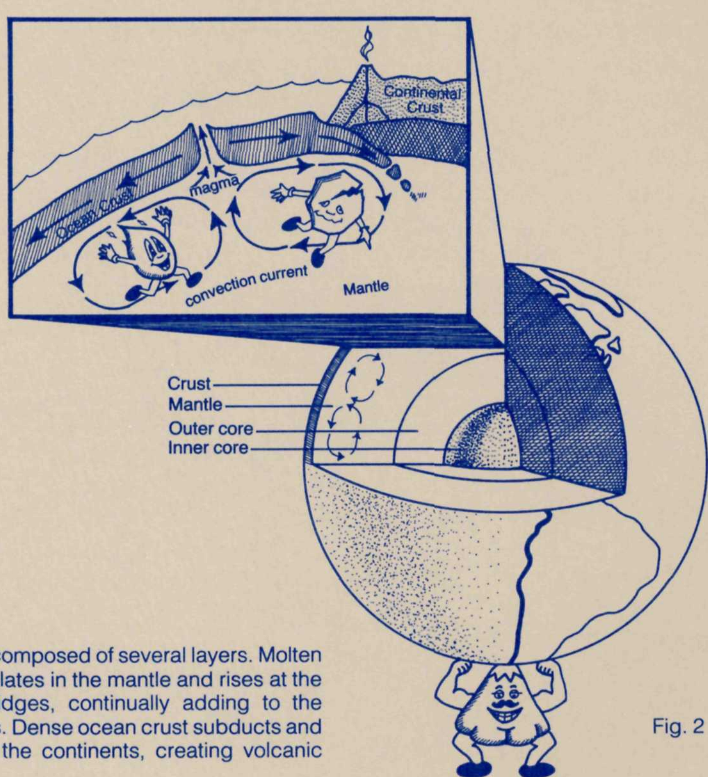


Fig. 1

The Earth's Moving Plates. The earth has eight major and several minor ones. Plates diverge at mid-ocean ridges, slide past each other along faults, and converge in subduction zones.

Molten rock in the earth's interior moves like air in a room heated with a woodstove. The hot air rises, flows across the ceiling, and then returns to the floor as it cools. Rocks of the **mantle** region slowly circulate in the same way, propelling the overlying plates and their passengers — the continents, oceans, and civilization.

Plates in Motion. Plate motion originates along a mountainous area on the sea floor known as an oceanic ridge (fig. 2). The centre of the ridge is a long crack in the earth's **crust** where **magma** rises, cools, and is added to the plate edges.



The Earth is composed of several layers. Molten magma circulates in the mantle and rises at the mid-ocean ridges, continually adding to the crustal plates. Dense ocean crust subducts and melts under the continents, creating volcanic eruptions.

Fig. 2

Most of the action takes place at the other boundaries, where two plates interact. When an oceanic plate thrusts underneath a continental plate the edge melts and becomes part of the earth's circulating interior again. In this **subduction zone** volcanoes, such as Mt. St. Helen's and Mt. Baker, spew some of the melted plate onto the continent. **Trenches** are sunk and new mountain ranges buckle upwards (fig. 3 & 4). Moving plates can also slip past one another — and snag — along **faults**, or fractures (fig. 5). When a critical stress has been reached, the bedrock suddenly gives way, releasing tremendous energy as an earth tremor. Along the San Andreas Fault in California, potentially damaging earthquakes are common. A similiar fault occurs off the west coast of the Queen Charlotte Islands where the Pacific Plate is moving northward past the North American Plate.

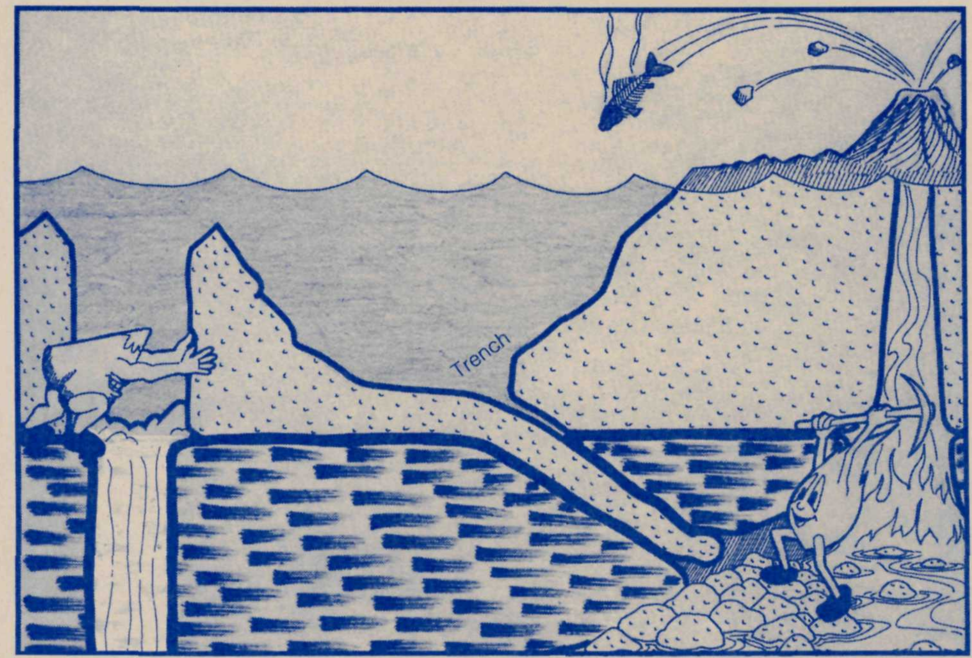


Fig. 3

Recycled Magma. Reclaimed plate material may erupt some distance from the trenches that mark subduction zones. Examples: Mt. Garibaldi, B.C.; Mt. St. Helen's, Washington.

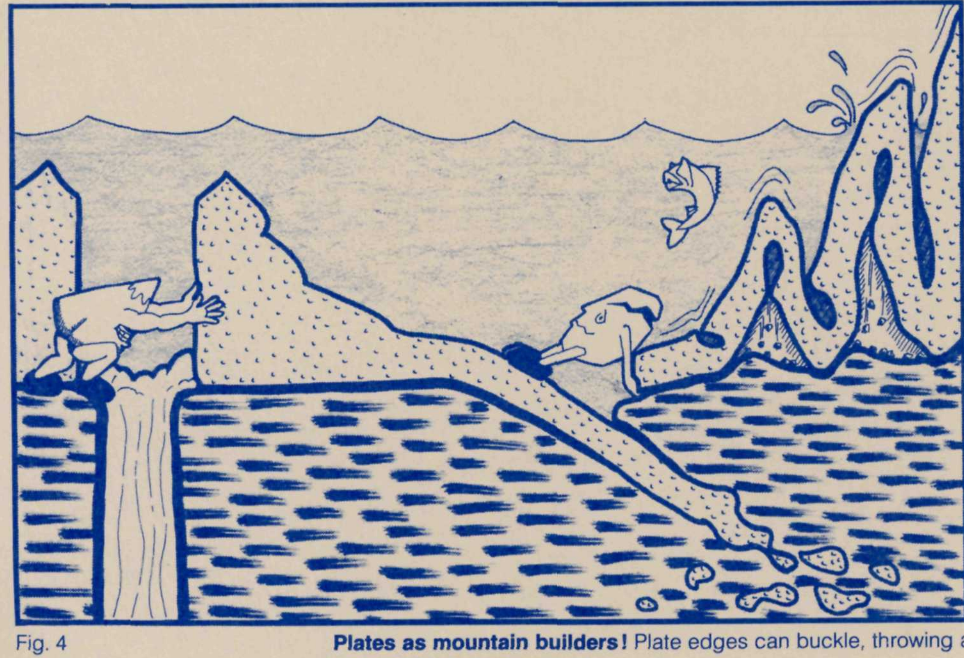
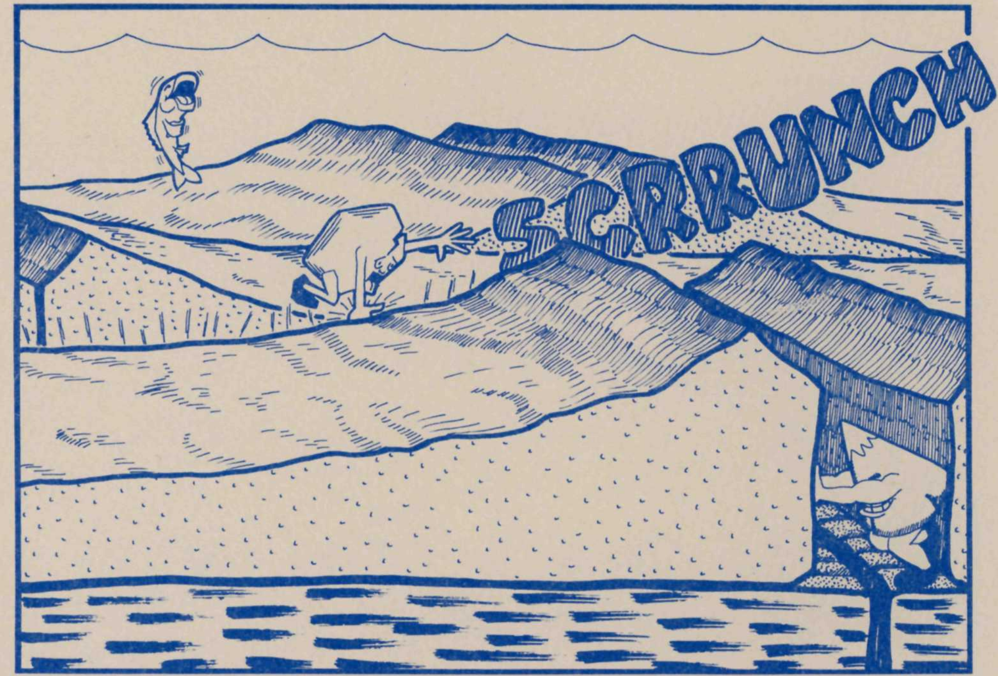


Fig. 4

Plates as mountain builders! Plate edges can buckle, throwing a new wrinkle.



Faults. In these zones plates bump and grind against each other. Not recommended as sites for cities, towns or buildings.

Fig. 5

Here on Vancouver Island we live near a plate boundary. There are three plates in our region: the Pacific, Juan de Fuca, and North American Plates (fig. 6). Only 200 km offshore, but 1600 m below the ocean surface, the ridge between the Juan de Fuca and Pacific Plates is being spread apart by molten **basalt**. The continual addition of new plate material here is driving the Pacific Plate toward Japan, while the small Juan de Fuca Plate (only 1/6th the size of British Columbia) forms a moving belt of rock that grinds straight toward us! At this moment, the leading edge of the Juan de Fuca plate bends downwards and plunges beneath the North American Plate 90 km off Long Beach. Over time this convergence has resulted in the uplift of Vancouver Island and the Coast Mountains.

The Juan de Fuca Plate "creeps" toward us at the rate of 4 - 5 cm each year. That's about the speed that your fingernails grow. In one day it travels no more than the thickness of a razor blade, but the effects can be dramatic!

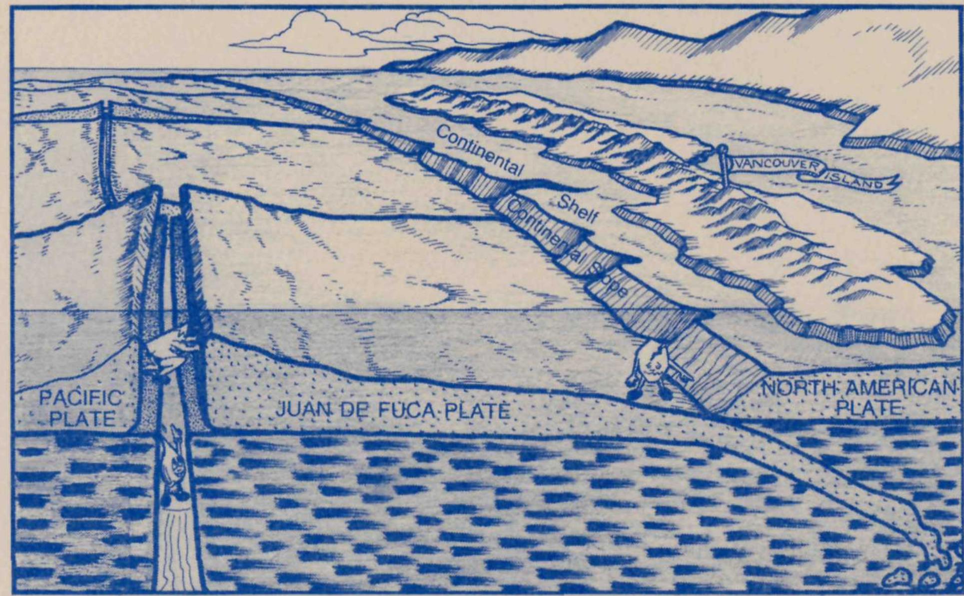
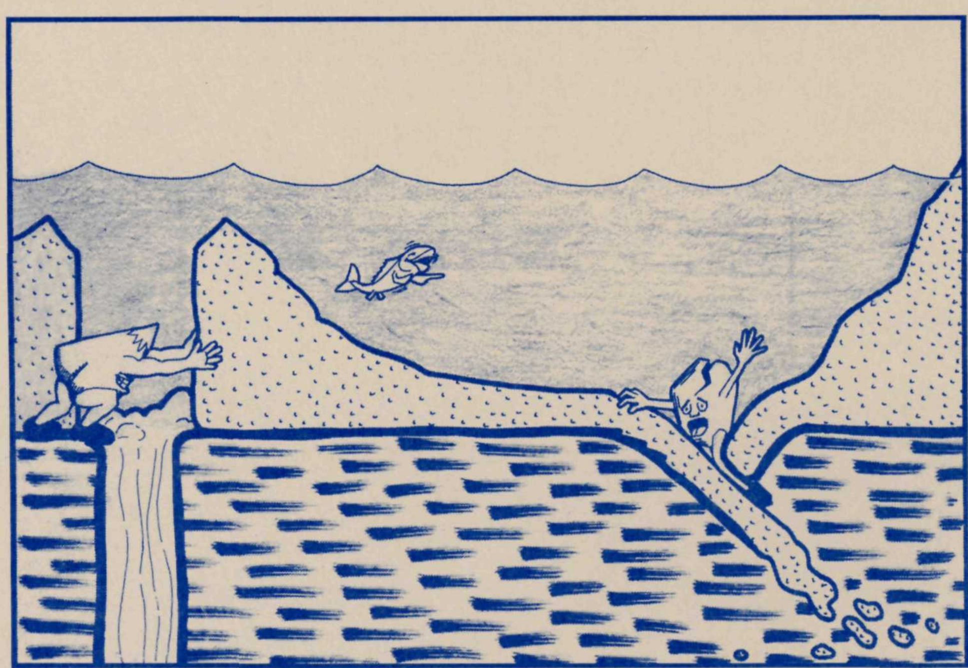


Fig. 6

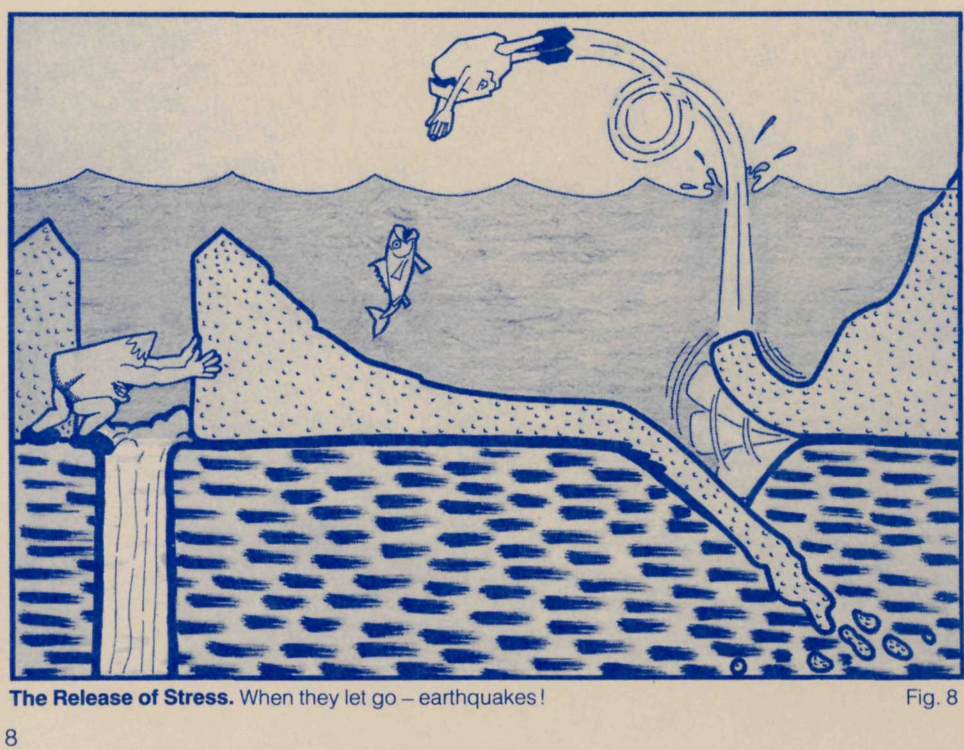
Offshore Plate Action. Magma added to the ocean ridge pushes the Juan de Fuca Plate eastwards. The North American Plate overrides this small plate. On the other side of the ridge, Pacific Plate rock moves slowly towards Asia.

When the Earth Moves. Tremors are frequent along the offshore spreading ridge, but most earthquakes occur where a plate subducts under the coast or grinds past another plate. Three or four times a month Vancouver Island or the lower mainland shake. Most tremors are imperceptible, but occasionally they are strong enough to rattle windows and sway chandeliers. Three or four times a century, with little or no warning, a big earthquake hits — strong enough to tear up asphalt and topple chimneys anywhere in western British Columbia (fig. 7 & 8).

Tsunamis, or seismic sea waves, are caused by earthquakes, underwater landslides, and volcanic eruptions. On the open ocean tsunamis are of relatively small height, but their speed can exceed 700 kilometres an hour. In shallower water, friction with the ocean floor reduces wave speed to 30 - 40 kilometres an hour, which creates a potentially hazardous pile up of water. The 1964 Alaska earthquake triggered a tsunami which swept across 1800 km of ocean to cause major wave and flood damage in the nearby communities of Port Alberni and Tofino.



Graveyard of Plates. At subduction zones, ocean crust slides under a continental plate. Sometimes plates lock together here... Fig. 7



The Release of Stress. When they let go – earthquakes! Fig. 8

Plate Collision. Two hundred million years ago the continents were joined together as one supercontinent called Pangaea ("all lands"). Pangaea was surrounded by an enormous sea (fig. 9). Magma upwelled into cracks, spreading the land masses apart and creating new ocean basins between them. Thus, North American began the long journey westward toward its present position.

Fig. 9

Continental Jig-Saw puzzle. The "fit" of the continents suggests that long ago they were part of one landmass, surrounded by an enormous ocean.

During the course of its slow drift, the western edge of North America collided with smaller plates bearing sediments and strings of **volcanic island arcs** that had formed far away in the ancestral Pacific Ocean. The smaller plates disappeared under the continent, but their crustal passengers, or **terranes**, welded onto the edge of the continent. Almost all of North America west of the Rocky Mountains grew by the accumulation of terranes: landmasses that came from somewhere else.

Vancouver Island is made up of parts of three terranes. The largest, Wrangellia, is thought to have rafted in from as far south as Mexico or South America. This terrane docked with the ancient edge of the continent between 60 and 100 million years ago. Ninety per cent of Vancouver Island, the Queen Charlotte Islands and the Wrangell Mountains of southern Alaska are the present-day remains of this landmass. The Pacific Rim and Crescent terranes collided with Wrangellia 42 million years ago. Most of these two terranes are wedged underneath Vancouver Island, although the Pacific Rim terrane reveals its rocks in the beach headlands between Ucluelet and Tofino. Unlike Wrangellia, the Pacific Rim and Crescent terranes are probably more local in origin, perhaps coming from northern Washington.

Slow Motion Sideswipe. The rocks of our area have more in comon with formations found in southwest Alaska and California than elsewhere in Canada. And they are some of the most travel-weary visitors to Pacific Rim National Park! Just about everything that can happen to rock has happened to these. They've been compressed, heated, shoved, relocated, and finally welded onto Vancouver Island.

The rocks you see in the Long Beach area were formed between 130 and 225 million years ago along a **continental slope**, perhaps only a few hundred kilometres away. There they remained for about 90 million years until moved northward and welded to Vancouver Island. This collision happened 42 million years ago as an offshore plate squeezed below the edge of the North American continent. Sediments and volcanic materials were scraped off the descending plate and plastered against our shores. The Pacific Rim terrane had arrived. It was a slow motion sideswipe — the impact lasting more than a million years (fig. 10)!

On the Rocks. During their journey here the rocks were subjected to intense pressure and deformation. Throughout the park you will see the resulting chaos of rock types that make up the Pacific Rim terrane. The black colour of these rocks is caused, in part, by a thin, living layer of lichens and blue-green algae.

Graywacke is the most common rock type in the Long Beach area. It forms the headland between Wickaninnish and Florencia Bays, as well as Radar Hill. Graywacke is a coarse-grained rock consisting of quartz, feldspar, and tiny fragments of volcanic rock.

Argillite is a dark siltstone derived from fine clays. The argillite outcrop below Green Point campground attracts visitors to its tidepools and mussel beds.

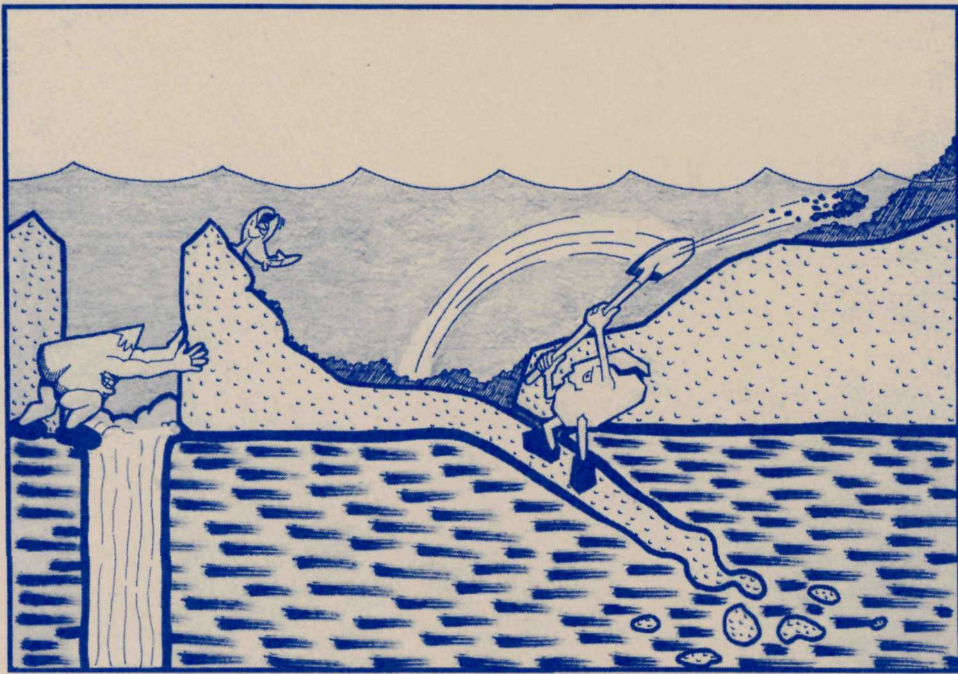


Fig. 10

Give and Take. Plates add terranes – ocean sediments and volcanic peaks – to the continents. In return, rivers and glaciers dump sediments into the ocean: future terrane material wherever the plates are heading!

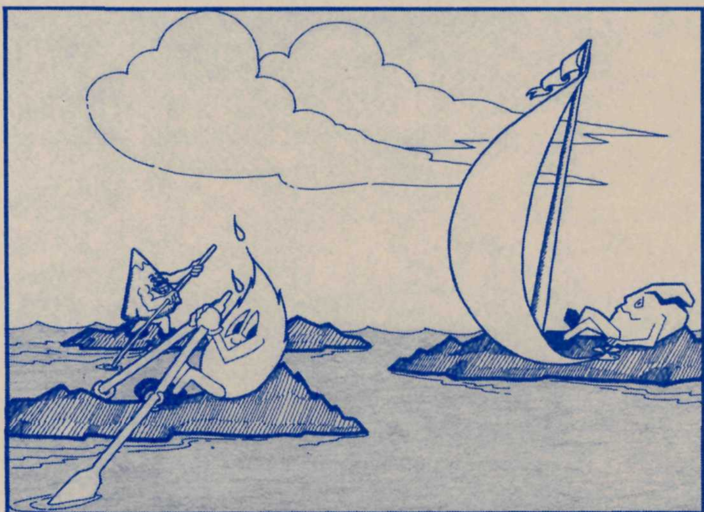
Ribbon Chert. On Box Island at the north end of Long Beach, alternating layers of argillite and brittle chert (a form of flint) have been squeezed and tilted until the once-horizontal layers now stand upright. The Pacific Rim cherts are formed from skeletons of one-celled animals called **radiolarians**. As these animals die their remains become part of the "rain" of material settling upon the sea floor. Some are preserved intact (fossils of microscopic radiolarians have been found on Box Island), but most are destroyed during their burial and compression into rock.

Pillow Lava. Red hot lava, billowing out of underwater volcanoes, cools quickly in seawater and forms a crust over the still glowing interior. This rapid cooling shrinks the lava into "pillow" shapes. Dark, rounded forms define this formation, seen in a framework of graywacke at the south end of Florencia Bay.

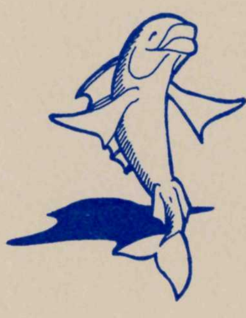
What next? Scientists believe that a large earthquake is now due on Vancouver Island. Historical evidence indicates that big tremors seem to occur here every 30 years or so; the last major ones happened in 1918 and 1946!

As the Juan de Fuca plate subducts beneath Vancouver Island it may be pushing the west coast up, and tilting the east side down. So hang on! Scientists predict that in 20 million years this plate will be totally consumed beneath Vancouver Island.

Some people think we walk on solid ground. Well, look again! For the last 200 million years we've been taken for a ride! As for the future, changes to our landscape will depend on where the plates are heading, and how fast they move.



"Civilization exists by consent of Geology – subject to change without notice."
Will Durant.



Published by authority of
The Minister of the Environment

QS-W237-000-EE-A1

Canada