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BRITISH COLUMBIA EARTHQUAKE

June 23, 1946

By ERNEST A. HODGSON

(With Plates X-XX)

AT about a quarter past ten, Pacific Daylight Time, on Sunday morning, June 23, 1946, a severe earthquake occurred at or near the centre of the east coast of Vancouver Island. It was felt as far south as Portland, Ore., and north to about Ocean Falls, while the point farthest east reporting the shock was Kelowna in the Okanagan Valley.

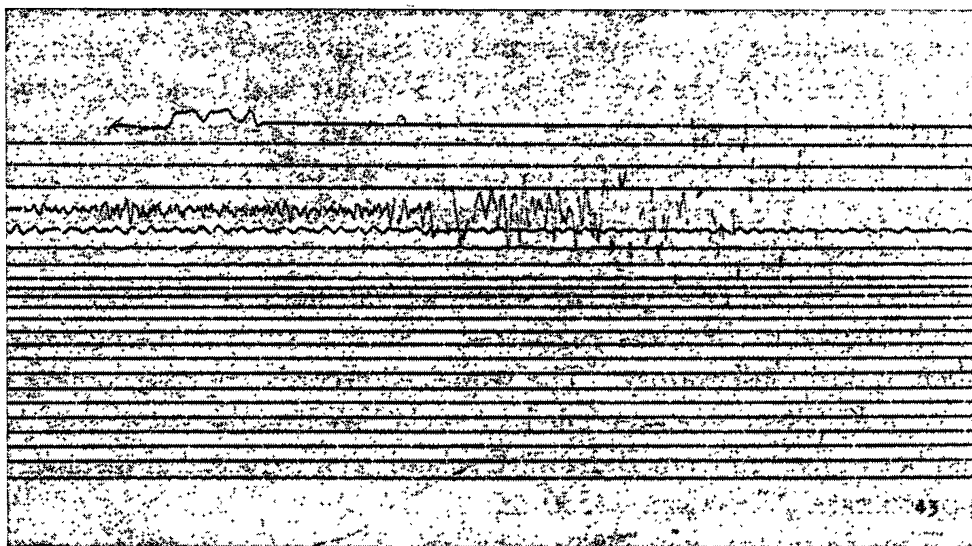


Fig. 43. Section of Milne-Shaw Seismogram, NS-Component, Ottawa.

PLATE X

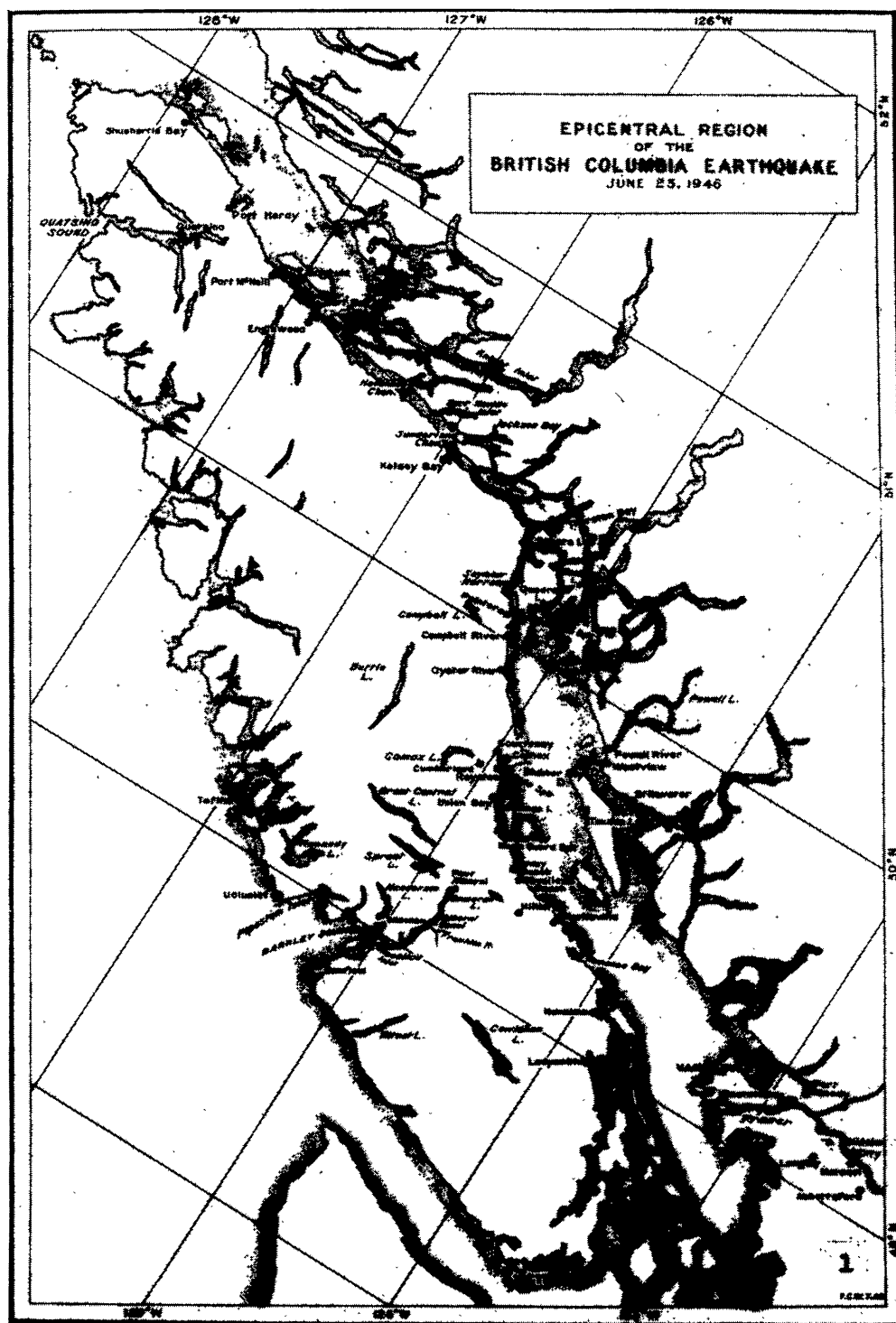


Fig. 1. Map of Epicentral Region and Adjacent Territory.

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PLATE XI



Fig. 2. Airplane View, Powell River.

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PLATE XII

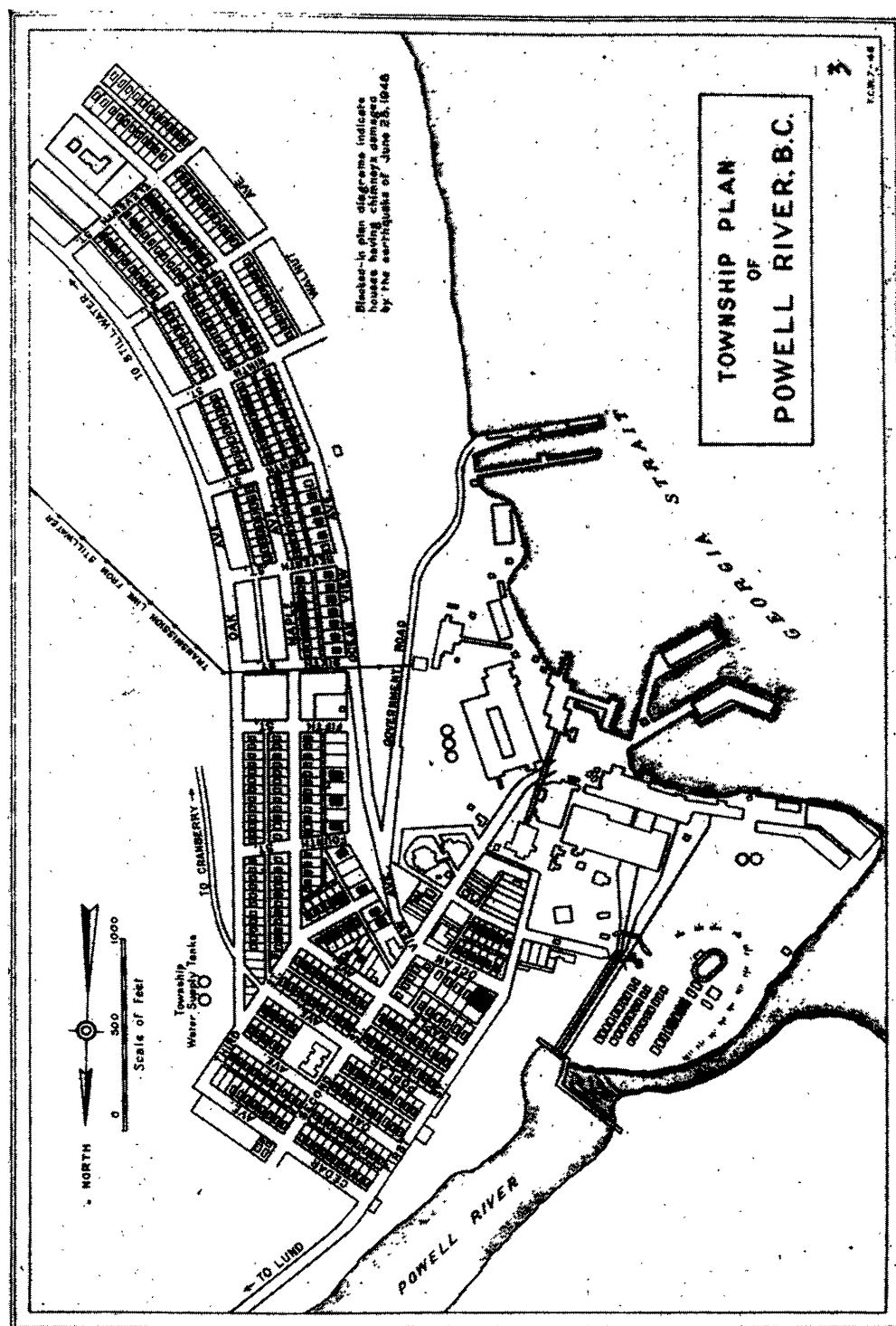


Fig. 3. Townsite Plan, Powell River.

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PLATE XIII

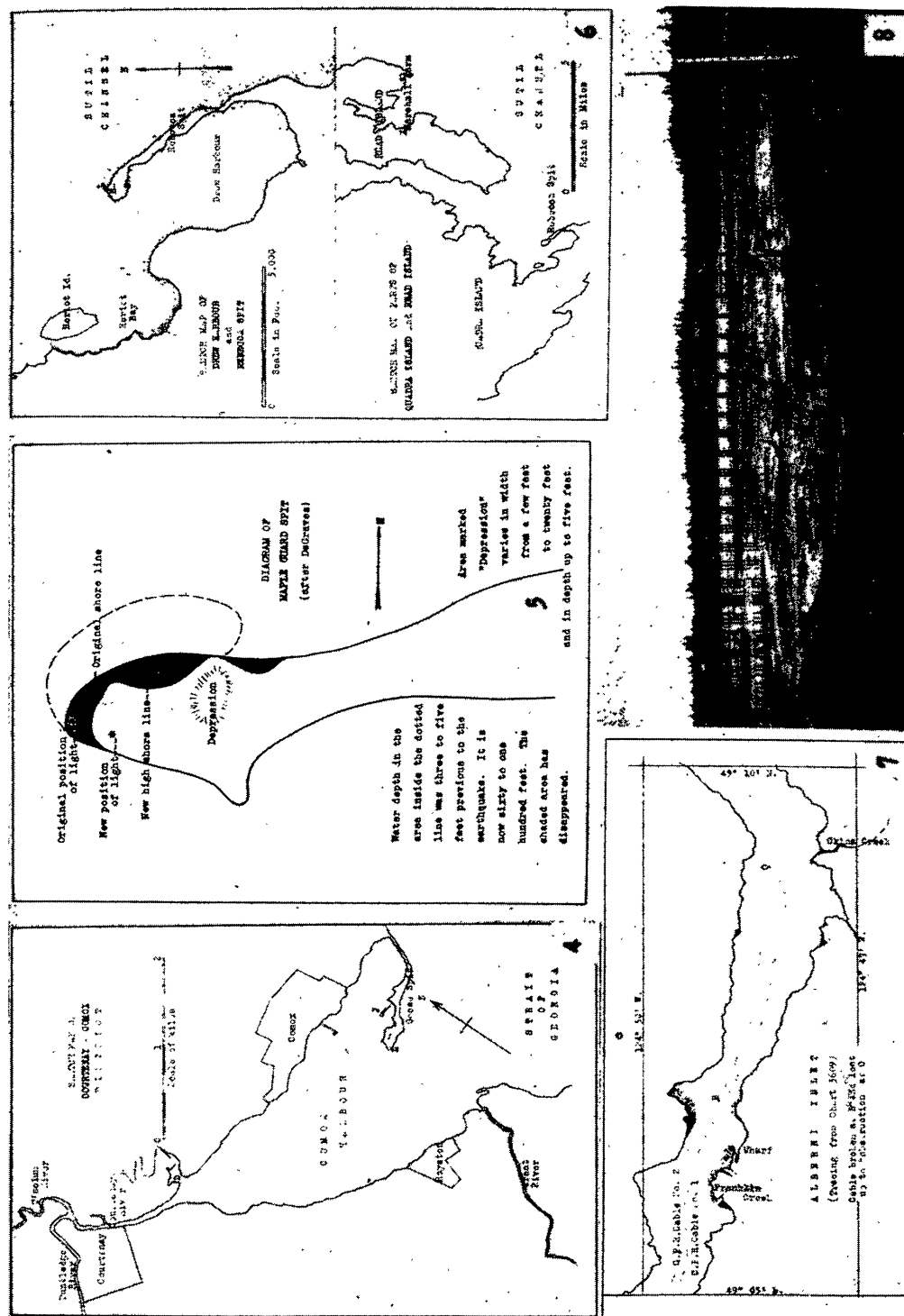


Fig. 4. Sketch Map, Courtenay-Comox.

Fig. 5. Sketch Map, Maple Guard Spit.

Fig. 6. Sketch Map, Rebecca Spit and Read Island.

Fig. 7. Sketch Map, Alberni Canal between Franklin Creek and China Creek.

Fig. 8. Damaged Skidway, HMCS. Naden II, Goose Spit.

PLATE XIV

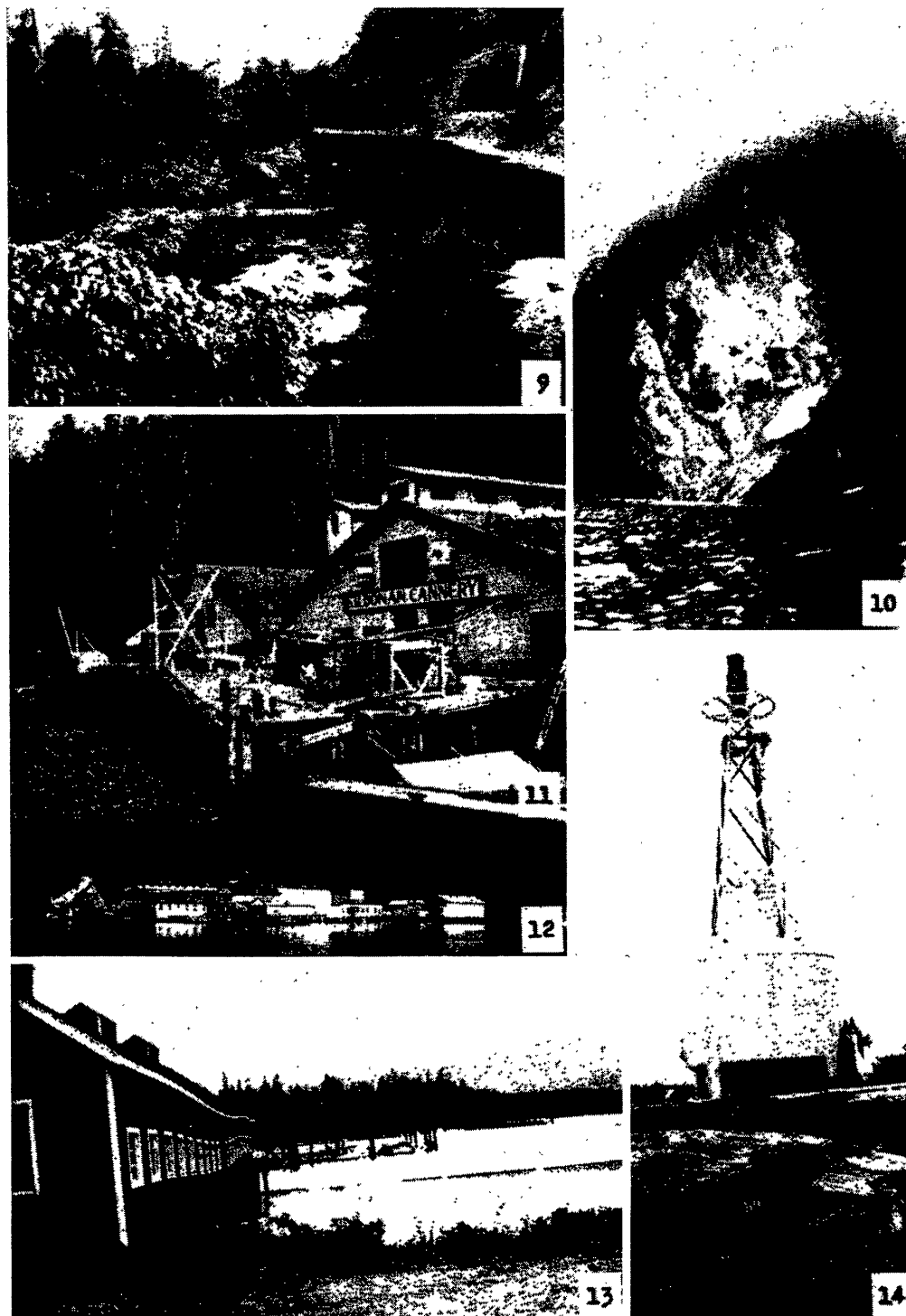


Fig. 9. Road Slump South of Kelsey Bay (Photo. Govt. Tel.).

Fig. 10. Rockslide, Henderson Lake (Photo. A. P. Larsen).

Fig. 11. Damaged Wharf, Kildonan Cannery (Photo. B.C. Packers).

Fig. 12. General View, Kildonan Cannery.

Fig. 13. Damaged Net Loft, Deep Bay Cannery (Photo. B.C. Packers).

Fig. 14. Navigation Light, Goose Spit.

PLATE XV



Fig. 15. Damaged Class Room, Courtenay Elementary School
(Photo. Silvertone).

Fig. 16. Fallen Chimney, Courtenay Elementary School (Photo. Silvertone).

Fig. 17. Damaged "Motion Block", Alberni.

Fig. 18. Damaged Post Office, Courtenay (Photo. Silvertone).

Fig. 19. Rotated Chimney, Port Alberni.

Fig. 20. Motor Launch "Uchuck".

PLATE XVI

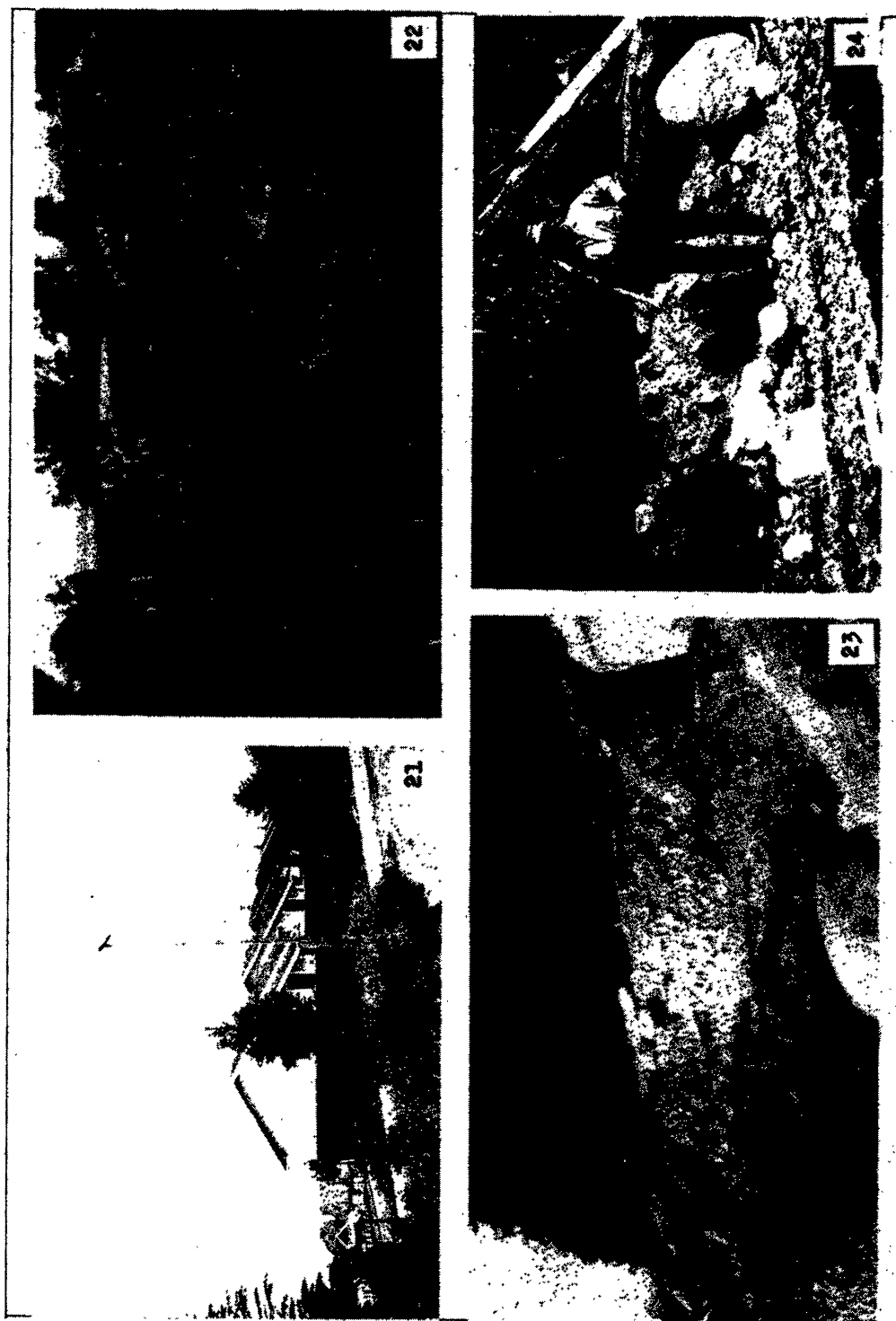


Fig. 21. Block of Houses, Powell River, between Tenth and Eleventh Sts., facing Ocean View Ave. (see Fig. 3).

Fig. 22. Fish Pond, Gus. Courte's, Westview.

Fig. 23. Welt on Beach, Westview.

Fig. 24. Gus. Courte at Welt on Beach, Westview.

PLATE XVII

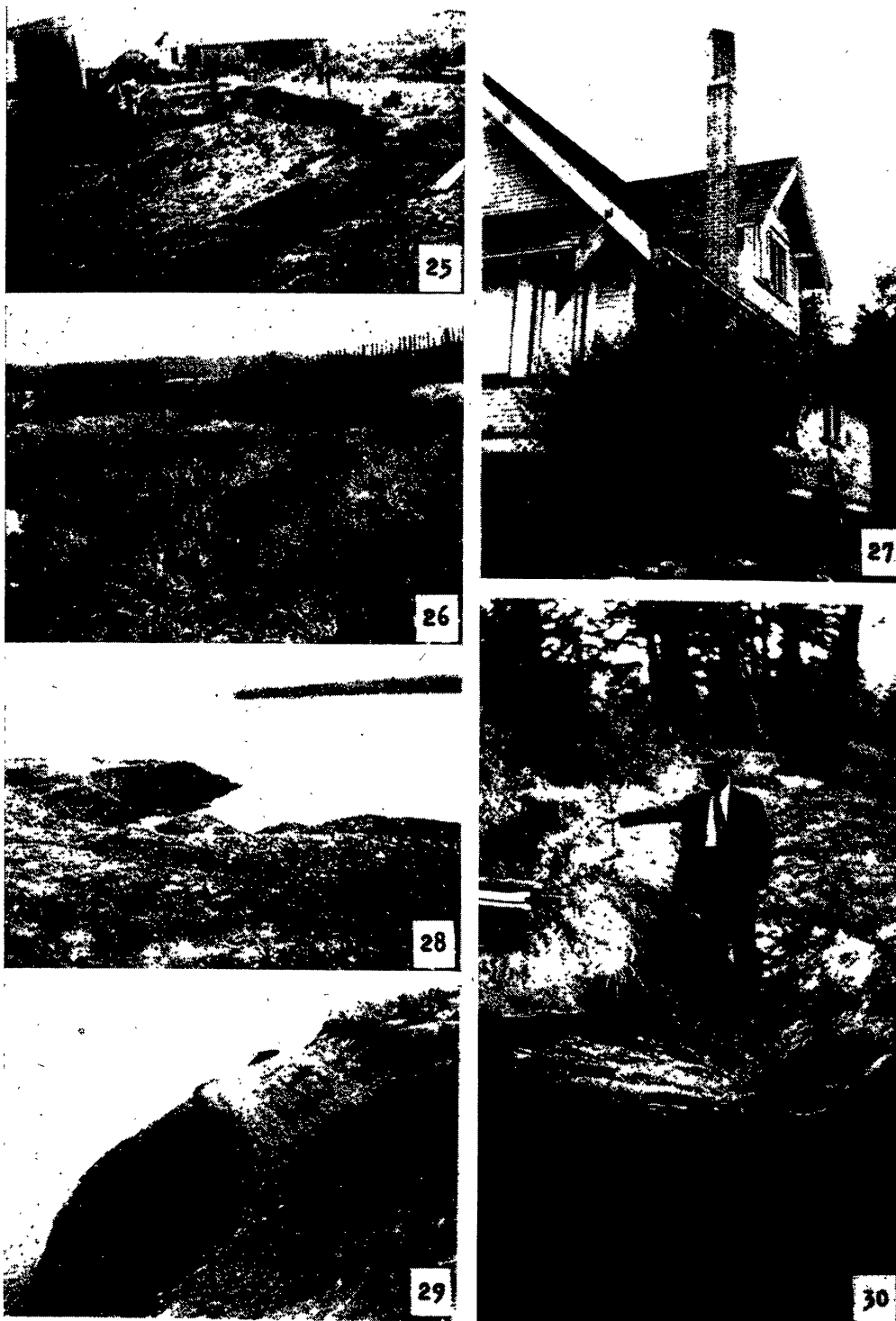


Fig. 25. Sunken Trough, Maple Guard Spit (Photo. B.C. Packers).

Fig. 26. Sunken Trough, Maple Guard Spit (Photo. B.C. Packers).

Fig. 27. Rotated Chimney, Powell River.

Fig. 28. Sunken Beach, Maple Guard Spit (Photo. B.C. Packers).

Fig. 29. Sunken Beach, Maple Guard Spit (Photo. B.C. Packers).

Fig. 30. Sunken Trench and Sand Blow, with Mr. DeGraves, Rebecca Spit.

PLATE XVIII

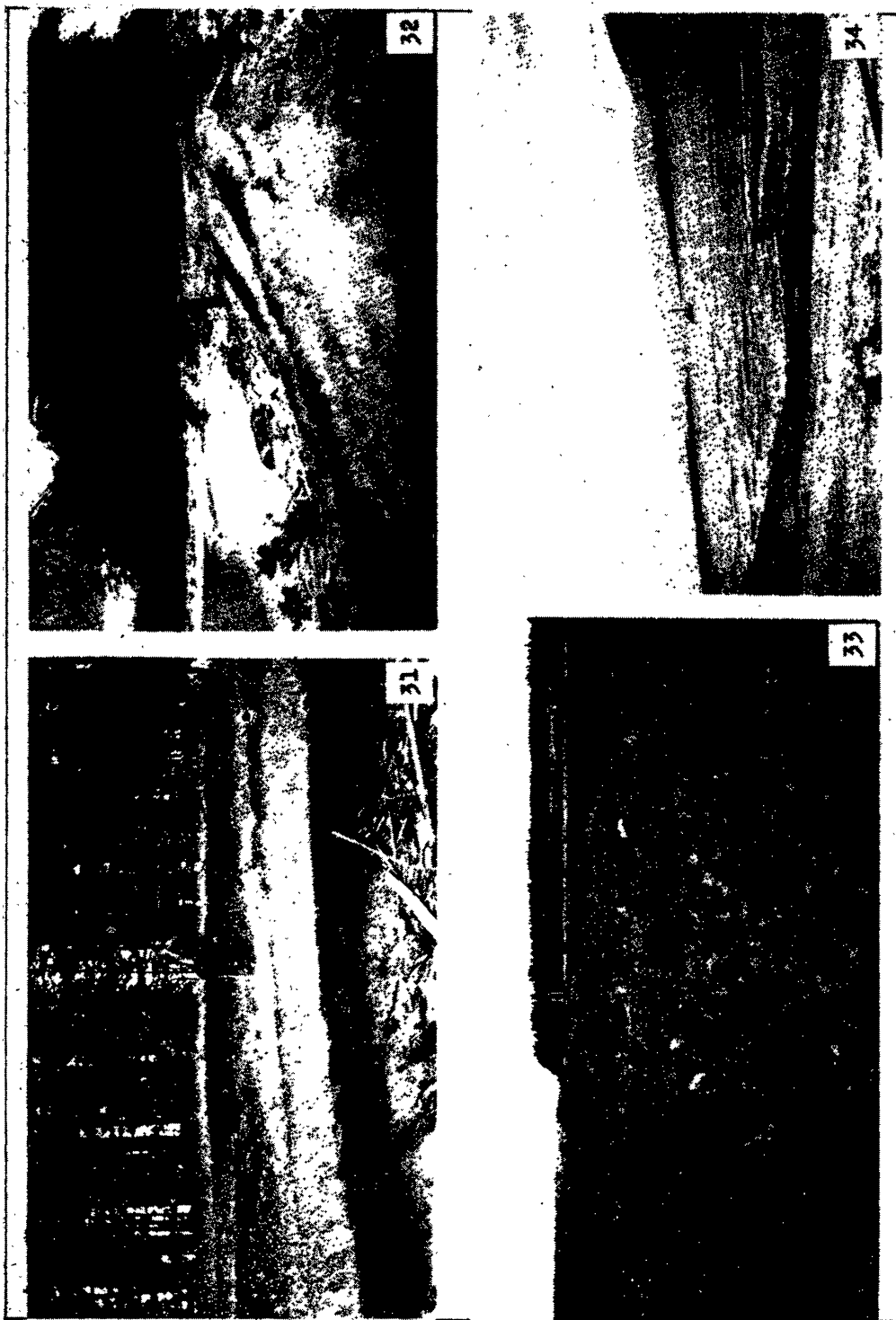


Fig. 31. Series of Down-drops, Rebecca Spit.

Fig. 32. Series of Down-drops, Rebecca Spit.

Fig. 33. Sunken Trench, Goose Spit.

Fig. 34. Sunken Beach, Goose Spit.

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PLATE XIX

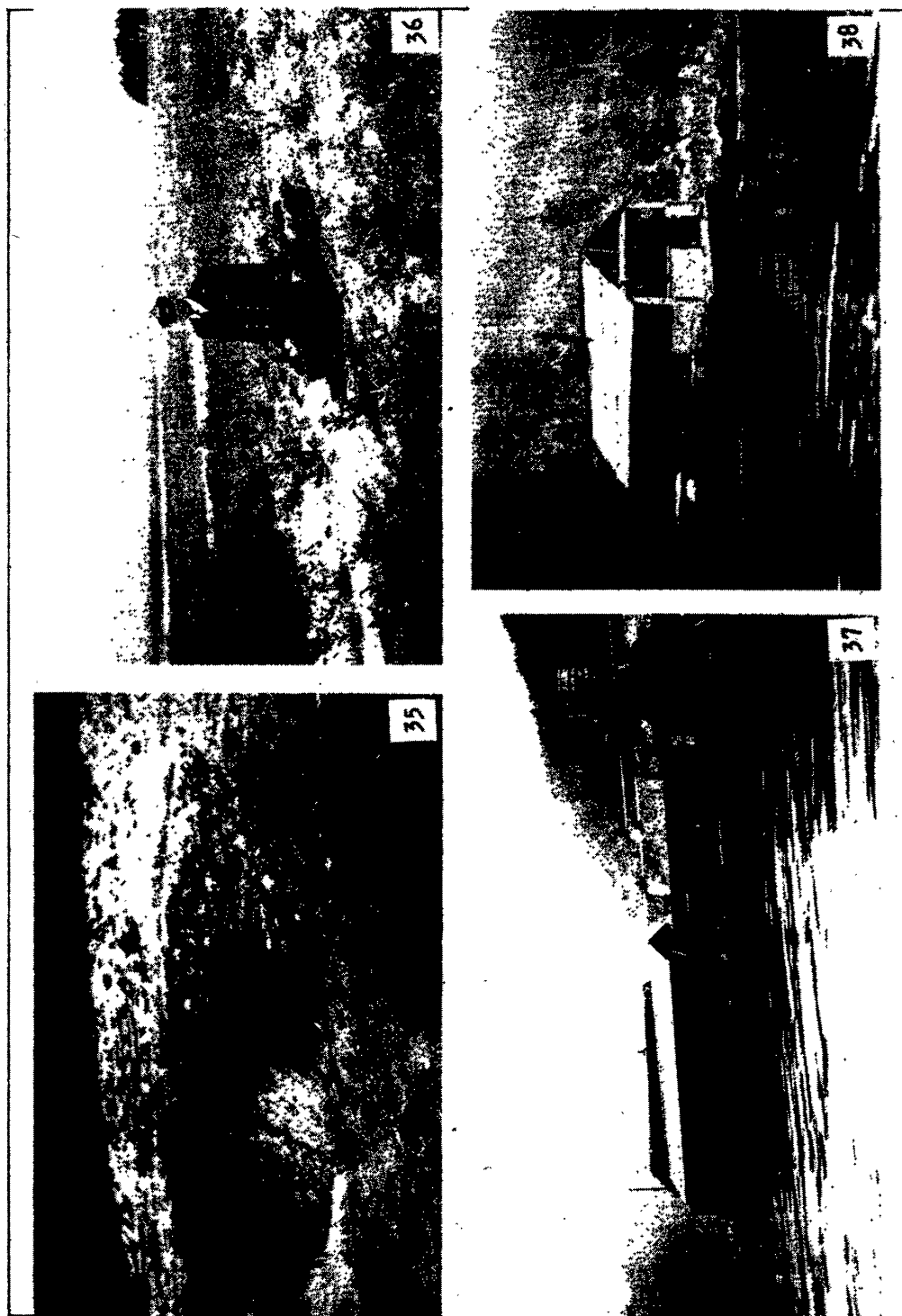


Fig. 35. Sand Blow, Goose Spit

Fig. 36. Sand Blow, with Lieut. Saxon, Goose Spit.

Fig. 37. Floating Camp, Comox Lake.

Fig. 38. Sunken Beach, Comox Lake.

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PLATE XX

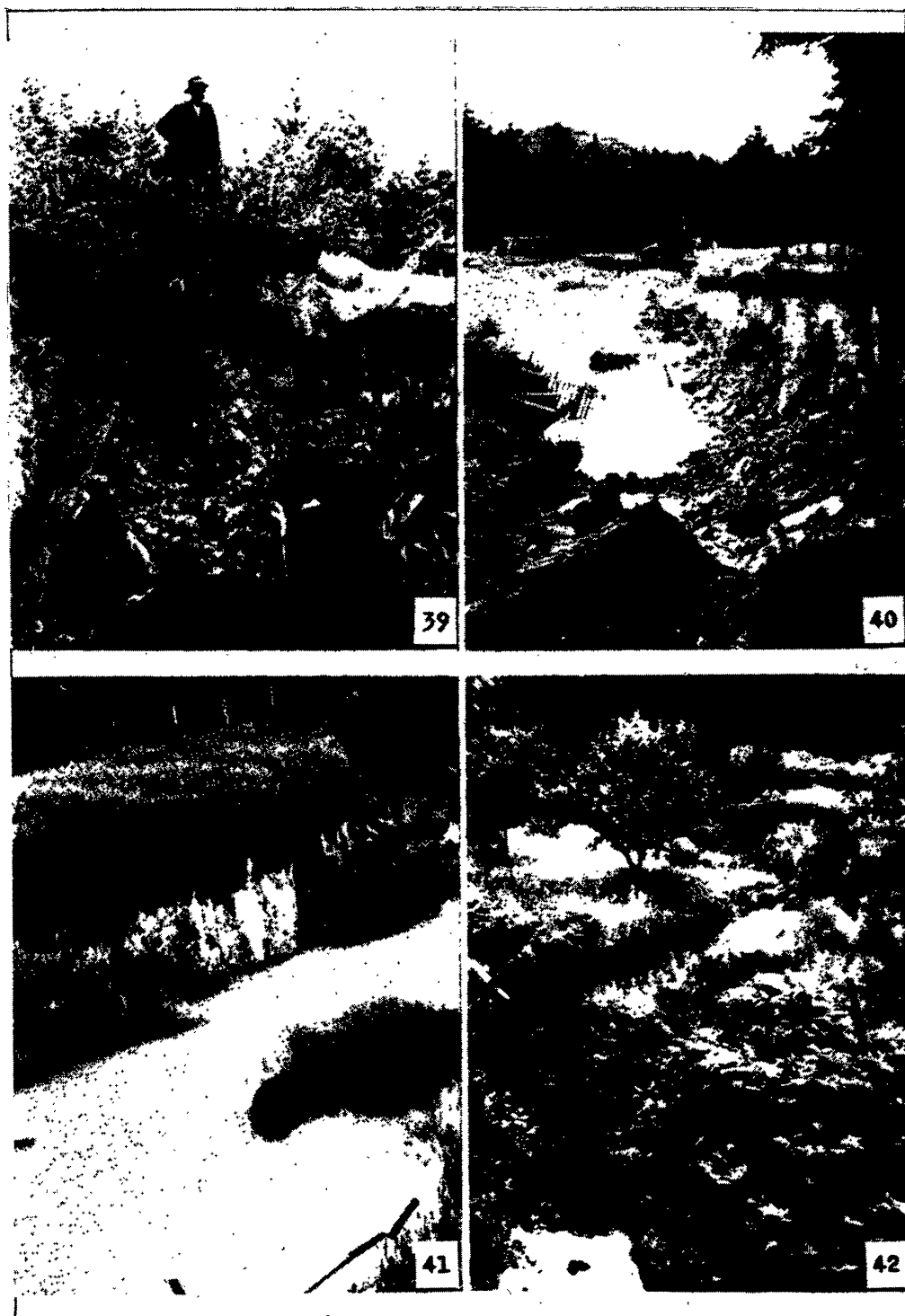


Fig. 39. Down-drops, Read Island (Photo. B.C. Police).

Fig. 40. Down-drops, Read Island (Photo. B.C. Police).

Fig. 41. Down-drops, Read Island (Photo. B.C. Police).

Fig. 42. Wrecked Orchard, Read Island (Photo. B.C. Police).

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An excellent record of the earthquake was registered on the seismographs at Ottawa (Fig. 43). It was at once established that the origin time of the shock was about 17^h 13^m 19^s U.T. (10^h 13^m 19^s a.m., P.D.T.), and that the distance from the epicentre to Ottawa was about 3700 km. (2300 mi.). This would define a circular arc, with its centre at Ottawa and a radius of 3700 km. The arc crosses Vancouver Id. from about Barkley Sound to Campbell River. It is to be noted that these first readings are only approximations, since the records from all stations should be considered together when making a final determination.

To locate the position of the epicentre on this arc requires a triangulation, using stations north or south of the suspected epicentre. It was hoped that Victoria would provide the data needed for this location, but it was found that the shock had proved too severe for the Milne-Shaw seismograph there. The rider connecting the lever system was dislodged, and the record was lost from the moment of the first onset. It was possible, however, even from such a meagre record, to get an approximate value of the epicentral distance. This was found to be about 140 mi., defining a point on the Ottawa arc a little south of Campbell River. This information was available at Ottawa as soon as the Victoria record arrived via air mail.

In the case of all legible earthquake records, the readings are at once transmitted by code telegrams to Science Service, Washington, D.C. There they are sent to the U. S. Coast and Geodetic Survey, where the combined data are used to make preliminary locations. More considered determinations are afterwards made at Saint Louis University. Finally, if the importance of the earthquake warrants, some seismologist is likely to take over a detailed study of the actual records, obtained from all the seismological stations in the world at which a good record was registered. Such a study is being undertaken by this Observatory. The requested records are now coming in. A very excellent one, recorded on a Milne-Shaw seismograph, has just been received from Bidston, England, at an epicentral distance of approximately 7300 km. (4530 mi.).

The first tentative location by the U. S. Coast and Geodetic Survey, sent in response to a telegraphed request from Ottawa, defined a position "in the Strait of Georgia, about twenty miles west

of Vancouver.” However, when the data were obtained from other stations and a further study made, the location (still tentative) was sent as “Lat. $49^{\circ}.9$ N., Long. $125^{\circ}.3$ W.”, a point about ten miles S.S.W. of Campbell River.

Newspaper reports began to reach the Observatory, telling of serious damage at various points on Vancouver Id. (Comox, Courtenay, Campbell River, Port Alberni, Kildonan, etc.). It was decided that the seismologist should make a field study of the earthquake, going first to Victoria to re-set and calibrate the seismograph, so that it would be in good order for recording any aftershocks which might occur.

Accordingly, he left as soon as plane accommodations could be secured, and arrived at Victoria Monday afternoon, July 1. The seismograph was put in order by Wednesday afternoon, July 3, and, during the same two days, an inspection was made of the earthquake damage in and about Victoria. The field trip then began and continued to July 23. The return trip was made by plane on July 24.

1. *Itinerary and Contacts, Sources of Information:*

During the three weeks spent on the field inspection, the following itinerary was followed:

July 1-3 Arrived Victoria, spent two days rehabilitating the seismograph and also following the routine field procedure: inspecting local damage, searching newspaper files and interviewing local observers.

July 4 At Vancouver.

July 4-5 En route Vancouver to Comox on board C. P. SS. “Princess Mary.”

July 5 Union Bay, Courtenay, Comox.

July 6 Courtenay to Campbell River, Quathiaski, Drew Harbour (Rebecca Spit), and return to Courtenay.

July 7 Comox Lake, Bevan, Cumberland, Royston, Qualicum Beach, Deep Bay (Maple Guard Spit).

July 8 Deep Bay and Maple Guard Spit.

July 9 Sunny Beach, Qualicum Beach, Cameron Lake, Alberni, Port Alberni.

July 10 Alberni Canal to Kildonan and return.

July 11 Alberni to Nanaimo via Hilliers, Parksville, Nanoose Bay and then, by bus, to Courtenay.

July 12 Comox and Goose Spit. HMCS. Naden II.

July 12-14 Powell River and Powell Lake.

July 14-15 To Vancouver.

July 16 Up Fraser Valley to Matsqui and return.

July 16-22 Trip by Union SS. "Cardena" from Vancouver to Prince Rupert and return with calls going and/or returning at Telegraph Cove, Englewood, Alert Bay, Sointula, Port Hardy, Shushartie Bay, Namu, Bella Coola, Tallheo, Ocean Falls, Butedale, Prince Rupert, Skeena River Canneries.

From July 5 to July 11, Mr. J. H. DeGraves, Safety and Fire Engineer for British Columbia Packers Ltd., accompanied the writer. This was a most fortunate arrangement, as Mr. DeGraves had made a previous inspection of the company's canneries at Deep Bay and at Kildonan immediately after the earthquake. He was familiar with the roads and the country generally and was able to arrange thorough inspections of properties owned and operated by B.C. Packers, not only on Vancouver Id. and adjacent territory, but on the northern trip as well.

The inspection of Powell River and Powell Lake was most thorough through the interested and whole-hearted co-operation of Mr. D. A. Evans, the Manager of Powell River Company, and his staff.

Captain Hicks of the "Princess Mary" made soundings over Comox Bar on July 5, which the writer was privileged to witness.

Many persons were met from time to time during the field trip from whom valuable information was obtained. Acknowledgment of these contributions will be given in the respective, appropriate parts of this report.

Requests for special official reports were made to: The B. C. Forestry Service, the B. C. Police, the Government Telegraph Service (Department of Public Works, Ottawa), the Canadian Pacific Telegraphs, the Hydrographic Survey (Department of Mines and Resources, Surveys and Engineering Branch, Ottawa), and the Lightkeepers at the various lighthouses on or near Vancouver Id. and the Queen Charlotte Ids. In each case most informative reports were received.

2. Earthquake Effects at Points Definitely Outside the Epicentral Region:

The epicentral region definitely runs up the east coast of Vancouver Id., from Deep Bay (opposite the south tip of Denman Id.) to

above Campbell River, including Quadra Id. and Read Id. at the north, and Comox Lake to the west of Courtenay. In addition, there are other locations which may or may not have taken part in the tectonic adjustment. These may be designated as Powell River and its environs and the Alberni Canal together with adjacent waters, especially opposite Franklin Creek on the Canal proper, and at Kildonan, on Uchucklicit Inlet.

Outside these principal and secondary regions of serious activity, the tremors were quite severe over all Vancouver Id., the adjacent small islands, and the coast of the mainland, up to the north-west corner of the Island. Beyond these sections, little damage occurred. The tremors were felt by only a few persons in various localities north of Ocean Falls. At Bella Coola, a new cement foundation was cracked but no other evidences of damage were found. A few houses in Vancouver and New Westminster were reported as suffering plaster cracks but these were either old buildings or were situated on a side hill.

At Matsqui, near Abbotsford in the Fraser valley, a small landslide in a deep, wet "bottom" changed the course of a creek. Landslides were also general all over Vancouver Id. The unusually wet season, the steep slopes so widely found in this province, and the very serious shaking by the earthquake were all responsible for the many slides, some of which would, undoubtedly, have occurred sooner or later without the earthquake. A further discussion of the landslides will be given in Section 3.

The tremors were quite severe in Victoria. About a dozen chimneys were wrecked. These were in two groups, one on Chapman street, the other on Vining street. Some of these chimneys were rotated, as will be mentioned in Section 4. Water mains were broken at two points: Manchester at Sumas and Hillside at Quadra.

Reports from various points on the Olympic peninsula indicate that the shaking was generally quite severe but that little damage was done. Several buildings in Seattle had minor plaster cracks, etc. The tremors were felt by nearly everyone in Portland. The fire chief immediately placed his equipment ready for emergency service but it was not needed.

In addition to newspaper accounts and personal investigations by

the writer at the places visited in his itinerary, much of the information for the conditions outside the zone of maximum disturbance was given by other observers. The region on the west coast of Vancouver Id., from Ucluelet to Tofino, was covered by reports from Mr. Rupert Thomas of Seattle, Mr. Don Mackenzie of Tofino, and several lighthouse stations. Conditions at Quatsino were dealt with in a report by Mr. G. Ildstead, a timber cruiser stationed there at the time of the earthquake. An account of slumps in road embankments south of Kelsey Bay (Fig. 9) was given by the Government Telegraphs (Dept. of Public Works, Ottawa). A general outline of conditions along the north coast of Vancouver Id. and adjacent territory on small islands and on the mainland was furnished by the B. C. Forestry Service (Messrs. L. C. Chamberlin and James Robinson of Thurston Bay, Sonora Id.). Fellow passengers on the "Cardena" told of experiences on the Queen Charlotte Ids. and at Smithers, B.C.

Lack of space precludes a detailed account of the conditions described. In addition to cracked chimneys, broken crockery and glassware, slumped earth fills on roads, crashing of dead trees, etc., the only unusual accounts were those given by the Forest Rangers.

Ranger Robinson reports:

At Jackson Bay (mainland just north of Kelsey Bay) the shore line (west side) slipped away, large rocks along the beach disappeared and the water deepened from 10 to 20 feet. Port Neville deepened from 5 to 25 feet in places at the head of the inlet, according to a local resident who is very reliable. In Havannah Channel (a little farther west on the mainland), it was noted that the water appeared to boil for some considerable time after the earthquake. Knight's Inlet (north of Havannah Channel) reported a number of large rock-slides, some of them seen by myself. All points from Green Point Rapids to the head of Knight's Inlet reported very heavy shaking, but no amount of damage except the odd broken dish and cracked chimney. The most severe shaking was reported by those people residing on mud flats at the head of bays and inlets such as Port Neville, Jackson Bay, etc.

Ranger Chamberlin reports:

Here at Thurston Bay on Sonora Id., the tremors were quite strong. . . . No damage of any extent resulted and no cracks in the earth have been noted. The sea, for some time afterwards seemed to surge slightly. At Deepwater Bay near the north end of the Seymour Narrows on Quadra Id., one of the loggers reports the tremors as quite violent and that the sea, in a matter of seconds, seemed to go from high-water to low-water and back again. No property

damage of any account or cracks in the earth, etc., have been reported. At the head of Bute Inlet another logger reported that there the ground seemed to go in waves like the sea and it was very difficult to stand. A few rockslides were started in this vicinity but no damage or cracks in the earth have been reported. Throughout this district which takes in from the Seymour Narrows to Sunderland Channel, the reports are much the same,—violent tremors but no damage of any account and no . . . cracks in the earth, etc.

3. *Landslides:*

Landslides were general over Vancouver Id. and adjacent territory. As previously stated, many of these would have happened in the near future without the added earthquake cause. Some of them occurred on mountain sides and are quite spectacular, as for example one on Henderson Lake (Fig. 10). Many of the slides did not reach the water of lakes or inlets, being stopped by forest growth above the water line.

Many reports were received of "cliffs 40 feet in height," etc., being formed where once a beach had been. These are a class apart. In such cases, in general, an alluvial fan, resting on a rocky ledge below the water line and sloping up to the nearby hills or mountains, slipped off into deep water. The former beach disappeared and, at the line of cleavage, a "cliff" now marks the broken slope. Such slides were reported from many of the lakes on the Island: Nitnat, Cowichan, Great Central, Sproat, Buttle, etc.

In some cases, the alluvial beach dropped away leaving no cliff, as observed in Cameron Lake, where the former bathing beach is now a steep down-drop in the water close to shore. A wild rose bush, in bloom, was found growing there in about a foot of water, some eighteen inches out from the new water line.

These slumps account for most of the disappearing beaches, but further consideration must be given to the case of Comox Lake (Section 11d) and to Maple Guard Spit (Section 11a), Goose Spit (Section 11g) and Rebecca Spit (Section 11k).

Some slides occurred several days after the earthquake. They were, no doubt, loosened by the tremors. One of these came down onto the highway at Cameron Lake on July 8. Large rocks, some weighing well over a ton, were involved. This potential slide had hung precariously over the road for about two weeks before falling. Fortunately no one was injured.

4. *Cemeteries Visited and Rotation Effects Observed:*

In the case of earthquakes in eastern Canada, the cemeteries afford an excellent guide to the epicentral region. They were not found particularly helpful in this investigation.

Cemeteries at Victoria, Courtenay (2), Comox, Quathiaski (on Quadra Id.), Campbell River, Cumberland, Qualicum Beach and Cranberry (near Powell River) were visited by the writer and others. The one at Nanaimo was inspected by Mr. A. F. Buckham the day of the earthquake. In none, was any certain evidence of earthquake action seen except in the Catholic cemetery at Courtenay. Here, an urn on the top of a very large monument shifted and rotated, but it was so high that it could not be conveniently inspected to determine the sense of the rotation. A small cross in the same cemetery rotated contra-clockwise about twenty degrees.

Most of the gravestones in many of the up-Island cemeteries are of the small pillow type, lying on the ground and generally set in cement. They could not have been affected by an earthquake. In other cemeteries, notably those at Victoria (Ross Bay) and Cumberland, there were many upright stones. No rotations, other than the single case mentioned above, were found. The Ross Bay cemetery was carefully inspected on the day of the earthquake by Mr. C. D. Maunsell, of the staff of the Dominion Astrophysical Observatory. No earthquake effects were found.

With regard to other rotations, the following were observed by the writer: A chimney at Powell River rotated clockwise (Fig. 27). One at Sunny Beach rotated contra-clockwise.

The following rotations (all clockwise) of chimneys in Victoria are authenticated by photographs reproduced in Victoria newspapers: 1355 Vining St. (*Times*, June 24), 1245 Chapman St. (*Times*, June 24), 1253 Chapman St. (*Colonist*, June 25).

A photograph, taken by a local resident in Port Alberni and purchased by the writer, shows that the chimney affected had turned clockwise (Fig. 19).

Reports of other rotations were given as follows: A chimney at Duncan was reported by Mr. Buckham as having turned clockwise. A large statue, housed in a niche over the door of Saint Joseph's Hospital, Comox, was reported by Mr. Meier, who re-set it, as having turned contra-clockwise.

In the case of the Saint Lawrence Earthquake of 1925,* many chimneys and gravestones turned. In general, those on the north shore turned clockwise; those on the south shore turned contra-clockwise. The epicentre is believed to lie between these.

In the case of the Cornwall-Massena Earthquake of 1944,† many chimneys and gravestones were turned. In general, those on the north shore turned contra-clockwise, those on the south shore turned clockwise.

In the British Columbia Earthquake, not many rotations were observed; all are reported above, a total of ten. These are distributed in such a manner that, if a line be drawn, associated with maximum disturbance (up the Alberni Canal to Alberni, across the height of land to Qualicum Beach, thence through Deep Bay and up the coast to Campbell River, Quadra Id., and Read Id.), then all situated south and east of that line turned clockwise and all north and west turned contra-clockwise.

There were some other rotations observed but the evidence as to the sense of rotation is conflicting. As observed by the writer and Mr. DeGraves, one of the cases was clearly contra-clockwise, but it is included in a group reported as having all turned clockwise. It is believed that this report was given by an observer regarding the turned part of the chimneys *from below*. "Clockwise" and contra-clockwise," as used in this report, are applied as looking *from above*.

No deductions may be drawn from the rotation data; they are much too few. The information is listed in this report merely to indicate that efforts were made to secure such data, and to show that the distribution of the few cases found does seem to have some relationship to the line of greatest disturbance.

5. *Tremors Observed on Board Ship:*

The Union Steamship "Cardena" was out in the channel after leaving Shushartie Bay en route to Port Hardy (see point A in Fig. 1), at the time of the earthquake. The man at the wheel reported to

*See this JOURNAL vol. 19, p. 169, 1925.

†*Idem*, vol. 39, p. 5, 1945.

Capt. A. C. MacLennan that the compass was trembling. This he verified, but they did not know, at the time, that an earthquake was the cause.

The C. P. Steamship "Princess Mary" was north-east of Texada Id. (see point C in Fig. 1). Capt. Hicks reports that the tremors were such that the ship seemed to have run over a sand bar. The engines were stopped and the tail shaft examined. Finding no trouble, they resumed their course but did not know there had been an earthquake until they reached Blubber Bay.

The Union Steamship "Ventura" was south-west of Texada Id. (see point D in Fig 1). There was general consternation on this ship. They thought at first she had struck a rock (not a sand bank). Then they realized they were experiencing an earthquake. This was reported by Capt. MacLennan of the "Cardena." It was not found possible to meet Capt. Suffield of the "Ventura."

The motor launch "Uchuck" (Fig. 20) was just off the port of Franklin River in the Alberni Canal. Capt. Young and his engineer, Mr. McCandless, thought at first that the tail shaft had broken. They report that "no wave of any kind appeared until we were down the canal several miles, when a series of gentle rollers crossed the channel from west to east, seeming to be generated at the mouth of Nahmint River," which enters from the west shore below Franklin River (which is on the east shore). These rollers were neither high nor narrow. They were long, gently-sinusoidal swells, very broad and flat. This evidence seems to be at variance with that given by a local observer to the C.P.R. Telegraph officials, investigating the broken telegraph cable. See Section 6 for further discussion of this point.

The barque "Pamir" was, according to a copy of the ship's log, authorized by the Captain and furnished by Mr. A. F. Jenkins, at Lat. $37^{\circ} 30' N.$, Long. $144^{\circ} 22' W.$, i.e., 1,021 miles south-west of Cape Flattery. They had been becalmed for about four days and were in an excellent position to note any tremors. None were felt, and they did not know anything about the earthquake until they received the radio news.

6. *Damage to Submarine Telegraph Cables:*

The telegraph cable from Blubber Bay to Powell River parted at the time of the earthquake. Information received was to the effect that the break occurred at a splice which had previously given trouble, that the cable was repaired in a few days, and that it was again in operation (July 12).

Serious damage was caused to the C.P.R. Telegraph cable in the Alberni Canal near Franklin River. The report by Mr. L. A. Raymond, Superintendent of Communications, is given as follows:

It was not the trans-Pacific cable that was damaged; it was the shorter cable approximately thirty miles in length connecting the cable station at Bamfield with our overland telegraph wires at Port Alberni. We have two cables laid along the inlet and they were both damaged that day.

A local person at Franklin River who witnessed the earthquake said that a ridge of water, twenty or thirty feet high, rose in the middle of the inlet, extending in a north and south direction. This rise in the water level caused a small tidal wave on each side of the inlet.

When we tried to pull up our No. 2 Cable to repair it, we found that it was held solidly on the bottom by some obstruction at a point approximately opposite China Creek. We were unable to move the cable by having a tug pull on it in all directions, or by winching it. We were unable to find either cable between China Creek and Franklin River by grappling. (See Fig. 7). This may have been due to the difficulties entailed in grappling for a cable in this depth of water. It has been conjectured that the bottom of the inlet may have developed a fissure and pinched the cables solidly in that section.

At a point about 800 feet north of Franklin River wharf there was a clean break in both cables. We were only able to find the Bamfield ends of these breaks. We were unable to locate any portion of the cables between these breaks and the obstruction opposite China Creek.

In the area of the obstruction, the Admiralty charts showed a depth of 300 feet. Our soundings showed a depth of 440 feet. In the area between China Creek and Franklin River, soundings were taken at several places during the search for the cables and we found the depth was 50 to 200 feet greater than shown by the charts. At one place on the east bank of the inlet, the tugboat skipper measured a depth of 100 feet where previously the rocks had been exposed at low tide.

Our electrical measurements showed another fault in the No. 1 Cable, at a point 8.3 miles from the Bamfield end. Due to the extreme depth of the water at this point, we have not yet attempted to grapple for the cable in this area.

With regard to the ridge of water "twenty or thirty feet high," as reported by the local observer to the C.P.R. Telegraph Co., and

a statement by Capt. Young that "the sea was like glass and no waves were observed until opposite Nahmint River, when long low swells were observed sweeping across the channel," i.e., from west to east, it may be noted that, at the instant of the earthquake and for some little time afterwards, Capt. Young and his crew were under the impression that some mechanical trouble had developed on their boat. Moreover, if the ridge were very wide and not in the nature of a wave, an observer on the boat would be in the poorest position to see it, while one on shore would have the best opportunity. It is quite likely that both stories are essentially correct. Certainly, the sea was smooth; there was no wind, and there were no waves as such. A long, smooth, wide swell would hardly be noticed on board the boat. It is likely too that the estimate of height is somewhat too great on the part of the land-placed observer.

Of particular interest is the complete agreement of all measurements that there was, if anything, a deepening of the channel as well as the shore line. This is a matter of some importance. If the cable was broken because a large mass of alluvium slipped off the submerged shelf at the shore line, and if no drop occurred in the channel, then the shore depths should be greater (as they certainly are) but the channel should be *less* deep.

If the Alberni Inlet is part of the epicentre proper and a drop occurred in the bottom of the channel, then it would be most important if this could be proved. Unfortunately, the earlier measures of depth, as given on the chart, are not echo-sounding profiles, but old Admiralty measures, not too precise as to depth, and even less precise as to position. In view of the scientific value of the facts, could they be established, a request is being made to the Hydrographic Survey to run echo-sounding profiles in the waters designated above and also throughout the main epicentral region described in Section 11. The Geodetic Survey has also been asked to re-run their line of precise levelling up the east coast of Vancouver Id. from Parksville to Campbell River.

7. *Effects in Coal Mines:*

No attempt was made to visit the coal mines in the Comox area, since reports received from residents agreed with accounts in the newspapers to the effect that no damage had occurred in the workings.

In the case of most earthquakes, miners underground seldom notice the tremors. This is natural. A miner's first care is to render all workings safe and capable of withstanding the concussion from blasts in adjacent workings. 'If loose is not to come down with a blast in a stope a few hundred feet distant, it will not fall because of an earthquake which does not originate in or very close to the mine.

Moreover, since mine locomotives and trucks are always being moved about on the same or adjacent levels during shift hours, a miner is not likely to notice the rumblings caused by an earthquake. At all events experience shows that they seldom do.

It may confidently be stated that none of the changes in land level or in water depths, occurring at the time of the earthquake, had any connection with underground excavations made by mining.

8. *Reports from Lightkeepers:*

In response to an official request for reports on the earthquake, from lighthouses around Vancouver Id., a summary for twenty-six stations has been received through Mr. W. L. Stamford, Department of Transport, Victoria. These accounts give an excellent review of conditions all around the coast.

In every case, the earthquake was felt; but, at most lighthouses the effects were not particularly startling. Windows were cracked, some oil or mercury (used to float the rotating lenses) was spilled, or dishes fell. Nearly every lightkeeper reports that no changes were observed on the sea. The single exception to this was at Sisters Rock (south of the centre of Texada Id. and east of the southern tip of Denman Id.). The report reads: "One tidal wave came at 10.22 a.m., seven minutes after the earthquake. The wave was seven to eight feet high. A second wave 100 feet from the first was four to five feet high. The speed was ten knots." This would seem to indicate roughly that the wave was generated at about Deep Bay or Union Bay.

A small amount of mercury was lost from the lens float at Pulteney Point lightstation (on Malcolm Id. off Port McNeill) and at Lennard Id. (off Tofino). At Gallows Point lighthouse (on Protection Id. off Nanaimo) "five or six pounds of mercury was shaken out" and at Estevan Point (on the west coast of Vancouver Id.

at about Lat. $49^{\circ} 25' N.$) "900 to 1000 lbs. (of mercury) spilled over."

The shaking at Estevan Point seems to have been particularly severe. "Some of the prisms were shaken right out of the lenses and some were ground to a fine powder, like flour. Two large panes on the N.E. side of the lantern fell out in very small pieces."

Other lighthouses on the west coast do not indicate any severe shock such as seems to have been experienced at Estevan Point. It is to be noted that this lighthouse is the one on the west coast nearest to the tentative location S.S.W. of Campbell River.

Lightkeepers stationed near Victoria and near Vancouver respectively, report having felt the tremors but state that they observed no other effects of the earthquake.

From Cape Mudge (southern tip of Quadra Id.) it is reported that "the colour of the tide in the rip changed to a green-blue within half an hour of the quake. . . . The fish stopped biting." It was the general experience of fishermen (supported by the records at the canneries) that the fish stopped biting throughout the epicentral region. Normal catches were not obtained for nearly two weeks. This may have been due to the fact that the sea became muddy and the trolls could not be seen.

Mr. Stamford states that reports from some other lightkeepers are expected and will be forwarded when received.

9. *Earthquake Effects at Points Possibly Within the Epicentral Region:*

The section which may be within the epicentral region but which, on the other hand, may simply have suffered "neighbourhood damage" due to proximity to that region may be designated as the Alberni Canal from Barkley Sound to Alberni and the mainland in the vicinity of Powell River. Arguments for and against considering these as truly epicentral will be given in each case. They may be discussed in order from west to east.

(a) *Kildonan:*

At the B.C. Packers' plant at Kildonan on Uchucklicit Inlet, damage officially estimated as from \$25,000 to \$30,000 was caused by the earthquake. It is believed that this was due simply to the

slipping off into deep water of part of the alluvial fan on which the plant is built. A photograph furnished by Mr. DeGraves is given as Fig. 11. See also Fig. 12. The front (seaward) end of the plant rests on piles which were driven into the outer edge of an alluvial fan. When the earthquake occurred, the front part of the fan slipped off into deep water. The centre of the wharf slumped down as shown in the photograph.

At the time, ice was being crushed for shipping fresh salmon. An ice plant at Kildonan supplies this refrigerant in large quantities. The crusher was operating on the wharf. When the slump occurred, the machine fell into the water, carrying the operator. He was unable to swim and, with a broken shoulder, was in some danger. He was rescued and sent to Alberni hospital.

At the back of the plant, a steep cliff rises for perhaps a hundred feet. The power plant penstock resting on trestles on this slope was not injured. Eleven chimneys were damaged, an oil tank sprang a leak and another slopped over. Goods were thrown from shelves in the store and in the cafe.

The major part of the damage occurred in the cannery. This was not in operation at the time, but the machinery was broken or thrown out of alignment. Most of the expense involved was concerned with putting this equipment into operation again. The damage here was reported in detail to his Company by Mr. DeGraves, who furnished a copy, which has been largely drawn upon in this report.

It seems safe to assume that the damage at Kildonan was the result of the slip-off of the alluvial fan. On the other hand, serious landslides occurred in this vicinity which indicate that the shock was intrinsically severe (Fig. 10). It would be most valuable could changes in depth be determined in Barkley Sound, Alberni Canal and Uchucklicit Inlet.

(b) *Franklin River:*

The effects at this point on the Alberni Canal have been discussed in connection with the report on the rupture of the telegraph cables (Section 6). The position of the Franklin River wharf is shown on the sketch map (Fig. 7). It is to be noted that it stands on the edge of an extensive alluvial fan at the mouth of the Franklin Creek.

There was no damage of any consequence to this structure according to Capt. Young. The "Uchuck" was just off this point at the time of the earthquake and has since regularly made Franklin River wharf a port of call. Whether or not the epicentre includes this section of the Alberni Canal, it is difficult to say.

(c) *Port Alberni*:

At Port Alberni there were quite a number of chimneys damaged, including one on the hospital, the latter resulting in some anxious efforts to rebuild it and restore full hospital services. However, most of the chimneys affected were in those sections of the town built on low-lying land. Those houses built on rock were little damaged. Losses incurred by stores due to the falling of goods from shelves varied greatly according to the type of terrain involved. The liquor store reported "no damage to the Scotch and only a few bottles of gin, rye and beer." This store is built on a rocky ledge.

The tower of the post office was damaged by the heavy clockwork shifting in its anchorage. The front of the building was barricaded and business continued as usual, entrance being gained through a rear door. A rotated chimney in Port Alberni is shown in Fig. 19.

The brickwork of a boiler was thrown down in the lumber mill of Bloedel, Stewart and Welch, breaking the pipe connections. It was not in operation at the time. The high smoke stack was not injured. This is rather remarkable since the mill is built on an alluvial flat at the head of Alberni Canal. The mill was shut down for some days after the earthquake while repairs were being made.

(d) *Alberni*:

In "Old Alberni" many chimneys were thrown down, but mostly in the case of older buildings or those on deep ground. Mr. Stevenson, the Ranger, states that his house, built on rock, suffered no damage. Nothing was thrown down in the house except one plate.

The "Motion Block" in this town was damaged as shown in Fig. 17. This received a good deal of newspaper publicity but was not very important as earthquake evidence. A flat roof on a brick veneer structure, none too well built and on deep ground, shifted back and forth, knocking several of the top courses of brick into the street. No one was injured.

As one drives east from Alberni toward Parksville, the houses show damaged chimneys for a few miles, as far as but not including Hilliers. The telephone wires, especially in Cathedral Grove section, were broken by falling trees.

To sum up: this region from Barkley South to Cameron Lake presents some evidence in favour of its having been part of the epicentre. If changes in depth in the centre of the Canal could be proved, it would have to be so considered. On the other hand, all the observed phenomena would be explained as "neighbourhood" damage if no such changes had occurred. Although Powell River is included in the section of suspect epicentral nature, it presents so many features of special interest that it is discussed in the next section.

10. *Powell River*:

The inspection of this town was particularly thorough through the valued co-operation of Mr. Evans and his staff. The town is built on a bank sloping rather steeply near the water's edge and then more gently back toward the mountains. Powell Lake, about a mile inland, discharges into the Strait of Georgia through Powell River, which is dammed and provides power for Powell River Mill. A photograph of the mill and townsite is shown in Fig. 2, and a plan of the latter, furnished by Mr. Macfarlane, Townsite Superintendent, is reproduced as Fig. 3.

The town is owned by the company and its maintenance is under the supervision of Mr. Macfarlane. He has indicated all the houses which suffered damaged chimneys. It is to be noted that these occur in groups. Further, no house in the section bounded by First and Third Streets and by Cedar and Maple Avenues was so affected. These are built on rock. Where the damage is not general for all houses in a block, the chimneys overthrown were those which had not been repaired for some years. In general, new or recently repaired chimneys stood the shock very well except in those blocks where all went down. It is difficult to say why whole blocks of houses should be affected while others with taller chimneys and nearer the steep slope to the Strait suffered no damage.

In view of the fact that sporadic damage is often found in earth-

epicenters and is usually difficult to report with certainty, the official town site plan of Fig. 3 is here reproduced. All except the one section above mentioned is built on sand and gravel and the damage is completely reported. Why the distribution should be as shown one cannot say with any certainty. The row of houses facing on Ocean View Avenue, between Tenth and Eleventh Streets, is shown in a photograph (Fig. 2b) taken from the north end of the school in the next block south. These chimneys are not nearly as high as is the one in the next block west, shown in the same photograph. Moreover, this tall chimney, together with others in its block, is nearer the steep slope shown in Fig. 2, than is the section of suspect epicentral nature next to it. The mill was not in operation at the time of the earthquake on Sunday morning. It was not damaged except for a few broken pipes. In the town there was a good deal of damage in the houses, where dishes, etc., were thrown down. One plate glass window was cracked; but others, in equally vulnerable houses, suffered no damage. Chimneys were damaged in Cranberry and Westview. One at Wildwood, just north of Powell River, near Powell Lake on the road to Lund, was turned 45° clockwise (Fig. 27). No damage was found in the cemetery at Cranberry, though there are quite a number of upright gravestones in the grounds. The type of damage above reported would appear to place Powell River definitely outside the immediate epicentral region, but two other cases must be considered. Reference has already been made to the breaking of the telephone cable between Texada Id. and Powell River. However, this parted at a splice which is reported to have given previous trouble. The second case is not so easily disposed of. About a quarter of a mile south of Westview, the steep bank bordering the Strait of Georgia becomes a cliff or bank of gravel about thirty feet high with its foot about high-water mark. The road skirts the top of this bank. At the time of the earthquake a section of the road slumped away but slipped only a few feet down the bank as indicated by the bushes and underbrush. At high-water mark on the beach, a great welt was formed, presumably accompanied by an upthrown sheet of water. This welt is 180 feet long, about 3 feet wide and was originally 5 feet high. The clay which came out of it is cracked deeply along the centre of the welt, and is of the

consistency of rather poorly-made cement. A piece of it, about the size of a baseball, carried for two weeks in a briefcase and since lying exposed on a desk, shows no signs of disintegration.

This welt was thrown up with sufficient force to break an fallen tree held in the bank by its roots and lying across the welt. The tree is about 18 inches in diameter but is badly weathered. The nature of the welt is shown in Figs. 23, 24. The tree which was broken is shown at the left-hand end of Fig. 23. In addition to the welt on the beach, but seemingly caused by a break half-way up the bank, a sort of crevasse is formed in the slope. It has opened up much as a cylindrical dunnage-bag opening appears when the zipper along its side has been pulled and the long opening gaps. This crevasse is about ten feet long, two to four feet wide and about five feet deep. It was not possible to get a good photograph of it. There seems to be no immediate connection between the welt, the crevasse and the slump on the roadway. All were caused by the earthquake, but the first was due to an up-thrust of water, and the other two to slump of a side hill.

Above the welt, beyond the road at the crest of the bank, is a lawn and garden owned by Mr. Gus. Courte. On the lawn are three fish ponds. The one shown in Fig. 22 has no retaining wall, the water being a foot or more below the grass bank. This pond is stocked with edible-sized trout. At the time of the earthquake, Mr. Courte was feeding the trout. When the shock came, he and the man with him threw themselves on the grass at the side of the pond. He states that the water in the pond was thrown into a swishing surge which dashed water over them and left barely enough in the pond to cover the fish. The writer was impressed with Mr. Courte's observing and reporting capacity in connection with other matters which he was himself able to check. There is no reason to doubt that this is also true. That the chimney on the adjacent house was not damaged may be laid to the freakish results seen elsewhere in the case of this earthquake (and others).

So far as could be found, the welt on the beach at Westview is the only case where the ground, surface or submarine, was raised by the earthquake. Newspaper stories of "cliffs thirty feet high," etc., refer to the steep face left when an alluvial fan breaks off and slips

into deep water ; or, in the case of Read Id., to which reference will be made in detail later, to the steep sides left bordering undisturbed level ground at the edge of a sink.

On the whole, it would seem reasonable, in spite of the welt on the beach, to consider Powell River as lying outside the immediate earthquake zone. At Stillwater, south of Westview, is a large power plant supplying Powell River Mill. No damage resulted there. Mr. Templeton, the engineer who inspected the plant after the earthquake, reported that there was no damage in the plant, but that the penstock began to deliver muddy water after the shock.

This penstock runs from the Gordon Pasha Lakes to Stillwater. It is over two miles long. The upper section is nearly horizontal and is cut through competent granite rock, except for the first 300 feet, which is in gravel. The tube is lined with reinforced concrete. It was de-watered and inspected carefully, especially at the point where it passes from gravel to rock and at the joint where the second half dips down to the power house. No damage was found. The surge tank, about 300 feet high, was also undamaged. If Powell River were in the epicentral zone, one would expect more evidence of it in the mill there and in the power plant at Stillwater, only a little over ten miles distant in an air line.

11. *The Epicentral Region:*

The section of the east coast of Vancouver Id., which certainly may be described as the epicentral region, extends from Deep Bay, opposite the south end of Denman Id., up to Campbell River, Quadra Id., and Read Id. Evidence that Comox Lake is also in that region seems conclusive. It is possible that a second disturbed fault extends south-westward from Comox, through Comox Lake, down the connecting valley to Alberni, and thence down the Alberni Canal to Barkley Sound. In any event, Comox Lake must be included as part of the epicentre. The evidence throughout the epicentral zone will be discussed with reference to the places affected, beginning at the southern end.

(a) *Deep Bay and Maple Guard Spit:*

Deep Bay is protected by Maple Guard Spit, which extends westward on the north side of the Bay between that body of water and

Baynes Sound,—the channel between Denman Id. and Vancouver Id. A diagram of Maple Guard Spit is reproduced (after DeGraves) as Fig. 5. On the spit is built the B.C. Packers' cannery, together with the houses occupied by those employed there. The effects of the earthquake are shown in pictures supplied by Mr. DeGraves and presented as Figs. 13, 25, 26, 28, 29.

The damage at this point was inspected by Mr. DeGraves the day after the earthquake, at which time the above pictures were taken. It was again inspected on July 8. Some of the details below were still in evidence, others had disappeared by the action of rain and tide, while others were greater than when seen two weeks before.

On the Sunday morning of the earthquake, a fisherman, Capt. Daniel Fiddler, was engaged in loading ballast into his motor boat anchored off the tip of Maple Guard Spit. He was using a dinghy without oars. Being close to shore, he simply pushed the dinghy back and forth from boat to shore as needed. When the earthquake occurred, the west end and north side of the spit disappeared. The extent of the change is shown in Figs. 5, 29. In the wave caused by the subsidence, the dinghy capsized. Fiddler was thrown into the water but his companion managed to get into the motor boat. Fiddler swam about for a few strokes and then disappeared. His body was not recovered until July 10, being found about a mile and a quarter distant from the point where his boat capsized.

As reported by Mr. DeGraves, the spit was markedly changed by the earthquake. As of June 24, he writes: "About twenty feet of the spit at the west end has disappeared. It was necessary to remove the navigation light at the end of the spit, back toward the east about eighty feet in order to save the light from going into the water" (see Fig. 29). By July 8, much more of the end of the spit had disappeared, leaving it as shown in Fig. 5.

Where the water at the north side of the spit was only two to five feet deep at high tide on a shelving beach, it is now a hundred feet deep. A deep bay encroaches on this side as shown in Fig. 5. Indentations in the beach (Fig. 28) indicate the extensions under water of down-dropped trenches on the spit (Figs. 25, 26). In places these trenches on the land reach a depth of five feet. It is to be noted that the trenches and depressions are not caused by the slump to the

The largest one crosses the spit in a north-south direction as an extension of the "depression" shown in Fig. 5. In places on the spit are craters several feet in diameter, some in the trenches, some on ground otherwise not marked by cracks. They are referred to as "sand blows." At the time of the earthquake, geysers of water, forced up under pressure, carried sand, mud and sea shells to heights estimated by various observers as about thirty feet. They are reported all along the coast, on the land and in the water from Deep Bay to points above Campbell River. On June 27, Mr. DeGraves was unable to reach bottom with a twelve-foot pole in some of the larger ones on Maple Guard Spit. By July 8, the elevated craters on this spit had become saucer-like depressions, some three feet in diameter and a foot or more deep.

A net loft, built on the south side of the spit, rests on piles which stand in water at high tide and are almost all uncovered at low tide. Around each of these piles there appeared sand blows. Some of the piles were pushed up, some were sucked down, (as indicated by barnacles on the piles), with the result that the net loft was badly distorted as shown in Fig. 13. The distortion there shown was all caused by the earthquake.

The houses on the outer end of the spit are arranged in two rows with a road between, running up the long east-west axis. Along this road, buried a foot or two below the surface, is a wood-stave pipe for supplying fresh water to the houses. An iron service pipe runs into this stave pipe opposite each house. The service was all disrupted and investigation showed that the service pipes had pulled out about eighteen inches from each side of the stave pipe, indicating a slump in both directions across the spit, toward the bay and toward the strait. Compare this with the later description of Rebecca Spit. (Section 11k.)

Some of the houses toward the outer end of the spit were in close proximity to the sinking trenches. These trenches continued to sink slowly for several days. The houses were vacated at Mr. DeGraves' direction, but were occupied after the inspection on July 8, all subsidence having been over for some time.

Damage to the cannery property, houses, etc., is estimated officially by Mr. DeGraves as between \$2,000 and \$2,500. Eleven chimneys were damaged, some thrown down and others cracked near

the roof line. Considering the shake-up at the end of the spit, it is remarkable that any chimneys stood.

Some of the fissures bordering the trenches were very deep. When first observed and filled in with from mere cracks to eight feet in depth. By July 8, they had all filled to within a short distance of the surface, but their position and width were still plainly visible. As the season was very wet and the soil is sand, it is remarkable that they remained visible for over two weeks.

It is to be noted that there is good evidence here of a true tectonic drop in the rocky foundation of the spit. There would seem to be no other explanation of a down-dropped trench with escarpments facing inward on both sides and running across a level section of the spit as shown clearly, for example, in Fig. 26. Again, it is noted that all changes reported are down and all water depths changed have become greater.

(b) *Union Bay:* Across the narrow end of the lake, say 1,000 feet distant, an old shack stood on a gently sloping beach with a stretch of sand. This village, between Deep Bay and Comox, is the shipping port for Comox coal, mined mostly in the vicinity of Cumberland. A long, high jetty or wharf carries loaded coal cars out to the side of coal-carrying ships. At the time of the earthquake, a large vessel was close-moored to this jetty. The earthquake caused so much relative motion between the ship and the jetty that the latter would certainly have been wrecked had the tremors continued much longer.

Hardly a chimney was seen undamaged in Union Bay. It is confidently believed that all must have required repairs. Here, as elsewhere in this district, the houses are of wood and not susceptible to damage except as to chimneys, windows, crockery, etc. Of all the villages and towns visited, the chimney damage in Union Bay easily rates the highest percentage. No other earthquake effects were observed or reported.

(c) *Rayston and Cumberland:* On the far side of the lake, the shore is now a precipitous drop. It was reported that "180 chimneys were knocked down in Cumberland." Nevertheless, when Mrs. DeGruys and the writer visited the town on July 7, they drove through it, street by street, making a careful observation of the chimneys. Counting 008, mostly new chimneys on old houses as having been damaged and adding those still obviously needing repair, not more than thirty at most could be

found,—about ten per cent. or less. No other damage was reported and none observed.

In Royston, a somewhat lesser percentage of chimneys seemed affected. Nothing further was reported in this village.

The cemetery near Cumberland was visited and closely inspected. No damage appeared, though some of the stones were quite unstable. There were a goodly number of vertical gravestones in this cemetery, which is quite large and well kept and evidently lies on deep gravelly soil.

(d) *Comox Lake*:

The disturbance on this lake was at the end farthest from Cumberland—the south-west end. Here, on the north shore, is situated the camp of the Comox Logging and Lumber Co. The camp is an extensive one, resting partly on the shore, partly on a raft, as shown in Fig. 37. Across the narrow end of the lake, say 1,000 feet distant, an old shack stood on a gently sloping beach with a stretch of sand, variously estimated as from 100 feet to 100 yards in width, leading down to the water which is, of course, not tide-water. At the time of the earthquake, this beach disappeared. The water rushed into the void, receding from the camp on the other side of the lake, so that the raft “bumped on the bottom.” Then it came back as a high wave. A man on the wharf, seeing it coming, ran for higher ground and only just got away, the water surging about his legs.

The wave washed inland about 100 yards, as shown by debris on the roadway. Mooring piles in the harbour were popped out and washed ashore in every case but two. A twenty-foot motor boat was carried inland forty-five feet and lodged in the bushes. A heavy donkey engine on the wharf was thrown into the lake. It is stated that the new piles, now being driven, are eighty feet long, to give the same above-water stand as was given previously by thirty-foot piles.

On the far side of the lake, the shore is now a precipitous drop, cutting under the front of the old shack as shown in Fig. 38. Soundings made on July 7 show that the water is now 33 feet deep at the shore line. The beach has disappeared for a length of approximately 300 yards. Trees formerly on the beach now stand in deep water or are canted over almost at right angles from the bank and float partly submerged.

This seems to have been a tectonic drop. If it had been merely a slump, the first wave would have been toward the camp, not away from it. Moreover, at this point, the shore is fairly level for a considerable distance back toward the mountain. A valley leads from this end of Comox Lake, south-westerly to Alberni, a fact which may or may not be significant. There is a possibility that a disturbed fault leads down this valley, but no evidence could be obtained in such wild country.

Landslides were visible in several places at this end of the lake, but no disturbance seems to have affected the north-east end. However, there are no structures there to be damaged until one reaches the small village of Bevan. Here the chimneys seemed, in general, to be old and in poor repair. Nearly all were visibly damaged.

(e) *Courtenay*:

According to the estimate of the Fire Chief, Mr. Cleland, about 25 per cent. of the chimneys were damaged in Courtenay. These were mostly in the central part of the town, known as "The Orchard." Some of these were on frame buildings, others on brick or brick veneer structures. See Fig. 18. Fig. 16 shows the hole in the roof of the Elementary School, caused by the fall of a large chimney. Fig. 15 shows the damage resulting in the class-room. Fortunately, the earthquake occurred on a Sunday morning. A large chimney on Hotel Courtenay also fell through the roof, causing considerable damage in one room and lesser damage in others. No one was injured by the fall of any of these chimneys.

There were some plate glass windows cracked, many stores lost heavily from broken dishes and bottles. The heaviest breakage loss seems to have occurred in the liquor store, where many bottles were broken. Several barrels of broken glass was the only reported salvage in this case.

No land cracks appeared in or near Courtenay except on the "Dyke Road." This does not afford much indication of earthquake violence and none of tectonic drop. The road at this point is a fill over a marsh. (The spot is marked D on the Courtenay-Comox map, Fig. 4). The road at this spot crosses the wide delta of a small creek. The side of the road simply slumped off for a distance of a hundred yards or so.

At various points near Courtenay and Comox, where houses were built on deep soil on sloping hillsides, the foundations gave way and the houses slipped off. In one case, a house under construction was completely thrown from its supporting timbers. The tremors in this region were severe. A considerable distance back toward the mountains, a valley from this end of Comox Lake, south-westerly to Alberni, was severely damaged. There is a possibility that a disturbance may not be significant. About 40 per cent. of the chimneys on the valley side have been damaged but no local estimate was obtained. It was observed that these chimneys were built on a level of the valley side. More generally, but not in the case of the houses, no disturbance seems to have been observed. The Alberni Hospital, a new brick building, was cracked in the interior in many articles, statues, etc. were thrown down. A large statue of Saint Joseph, standing in a niche over the entrance doorway, was turned 45° contra-clockwise, as has been reported previously. No other damage was caused in the building or in the cemetery which adjoins the grounds.

Some of these were on frame buildings, others on concrete. Lying partly across the mouth of Comox Harbour is Goose Spit, on which is established a naval training base, HMCS Warden. This narrow neck of land received a severe shaking. The water mains were disrupted and the septic tank was cracked, necessitating the evacuation of the cadets on July 20. Referring to the sketch map (Fig. 14) it will be noted that the coast line from Courtenay to Royston runs south-east and lies roughly parallel with the right-hand side of the map. A submerged sandbank known as Comox Bank or Kelp Bar runs from a point to the right of Goose Spit (parallel to and just off the edge of the map) down to Denman Id. On July 5, Capt. Hicks of the "Princess Mary" took soundings over this Bar, finding a depth of 27 feet, whereas according to his chart, the depth at that tide should have been 6 feet. This would be important if it were established. Referring to Fig. 1, it is to be noted that at low tide, it is necessary for steamers to go south around Denman Id. and back around the north end of Texada Id. to reach Powell River. If Kelp Bar has sunk as much as indicated by the above soundings, a scheduled service could be run directly from Comox to Powell River.

This matter being of considerable importance, the Hydrographic Survey is taking echo-sounding profiles in these waters. The Acting Hydrographer, Mr. W. K. Willis, states that a preliminary run failed to indicate any such changes in depth. A final report on this work is not yet available. The precise levelling to be done by the Geodetic Survey, as previously mentioned, will be carried in to Comox (but not to Goose Spit, no previous benchmarks having been placed thereon).

At the jetty on Goose Spit, the piles are very long. The tides are of the order of fourteen feet at this point. At the time of the earthquake, the jetty sagged toward its seaward end due to a leaning forward of the piles, pulling the shore end outward about a foot. As this is a very heavy long jetty, the effect is indicative of considerable strain. A good view of the jetty at low tide appears in the background in Fig. 8.

Some time previous to the earthquake, Lieut. Saxon had marked on one of the piles the actual height attained by a "high-high-tide." After the earthquake, he marked the actual height attained at a given high tide. This second mark was eight inches above the earlier one and the "paper difference" between the two tides was two feet. This would seem to indicate that the jetty and the sea floor on which it stands had sunk about two feet eight inches, plus or minus, allowing for fluctuations from tide-table values.

On the inside of the little bay, south of the jetty, is built a very substantial skidway for taking barges and boats up the bank to a repair shop. This skidway was put out of commission by the earthquake, as is shown in Fig. 8.

Cement walls backing the targets at the shooting range on the narrowest part of the spit were cracked by the shock, as were the "obstacles" used in the commando training.

At various points on the spit, deep cracks appeared which were still very well marked on July 12. Running diagonally across the end of the spit, about a hundred feet behind the navigation light (see Figs. 4, 14) runs a trench about fifteen feet wide and more than a hundred yards long. There is a distinct down-drop of something like a foot (Fig. 33). This extends south-easterly and crosses the beach out into the Strait of Georgia (Fig. 34).

On the spit, at the points marked by two small dots (Fig. 4), are

the craters of two sand blows. These are 65 yards from the nearest high-water mark. The craters are about 5 feet across and 3 feet deep. The mud, sand and sea shells thrown up by the geysers are scattered uniformly over a circle 100 feet in diameter. Both craters are shown in Fig. 36 (the second beyond Lieut. Saxon and on a line with his shoulders), and a close-up of one appears as Fig. 35.

Those in the immediate vicinity of a subsidence or of a landslide report "tidal waves" of which the estimated heights range from six to forty feet. Undoubtedly, these waves *were* generated in the various localities, but there seems to be no evidence of any large "tidal" waves anywhere on the coast or on the lakes. On Goose Spit there is some evidence that there was a wave, and that it was not very large.

(h) *Merville*:

Although the writer passed twice through Merville, in company with Mr. DeGraves, no investigation was made other than to note that many chimneys were broken all along the road from Courtenay to Campbell River. However, a letter from a farmer, Mr. H. R. Treherne, gives some interesting details. He writes:

I was deeply interested in the report of your recent visit to Courtenay, in this week's *Free Press*. I believe I can clear up some of the questions that appear to be of great value to you:

- (1) The quake came from the straits.
- (2) There was absolutely no noise preceding the quake.

I live in the Kitty Coleman District and my land runs down to the sea and faces approximately east. I was working on a fence and facing the sea, when suddenly, down the hill, the earth looked like a large snake coming up the hill, yet where I was standing was perfectly still for a second or so. After the tremor reached me, the roar commenced, tops of trees fell and bedlam was let loose. You can rely upon this information as I am not of the imaginative or hysterical type.

This dramatic account of what must have been an interesting, if somewhat terrifying, experience raises a point which may be discussed here. The account states that, until the wave reached him, there was no noise, no preceding roar. The same report is given by Mr. Peyton (Wireless Operator on the "Cardena"), regarding his observations at Abbotsford in the Fraser Valley. He says that, on previous occasions when they had experienced an earthquake of much lesser intensity at his home (where he was at the time of this earthquake), the cows were disturbed and the chickens (and even the partridges)

made noises indicating their alarm. In this case, there was no noise until the house shook, and even then there was no subterranean roar. The cow lay, placidly chewing her cud, and the chickens were undisturbed in their yard; no partridges were heard.

On the other hand, reports from nearly all other places indicate that there was a roaring noise from beneath the ground, before the shaking began and continuing throughout the earthquake. These noises were said to have been very pronounced on Read Id. Newspaper accounts seemed to indicate that these noises were heard there for some time after the shock and that the residents were, on that account, apprehensive. A reply to a direct question, given by Constable MacAlpine in a letter dated August 6, states that the noises were heard only at the time of the earthquake (see Section 111).

(i) *Campbell River:*

In this town, about 75 per cent. of the chimneys were overthrown. Goods were damaged in falls from shelves. Crockery and glassware were broken. Windows were cracked. Considerable damage, due to falling chimneys, was reported from the Willows Hotel.

Near Campbell River a fairly steep slope, covered with soil, grass and trees, rises from the landward side of the highway. Several slips occurred on this slope. At one place a house (foundations, lawn and garden, complete) slipped down and forward toward the road for a distance of about five feet. This gave rise to the widely-circulated report that a "hill had shifted 30 feet."

Mr. Underwood, the Ranger, lives in a house on the shore. He came out on the lawn as the earthquake struck and saw several water spouts rise in the strait. At Painters in Duncan Bay, a few miles north of Campbell River, there was "a boiling up of black mud, making bulges in the bay of about the size of an automobile." At this point most of the chimneys were damaged. One or more were rotated but it was not possible to determine the sense of rotation, clockwise or contra-clockwise, as they had since been repaired.

Campbell River is normally a clear stream. It became muddy at the time of the earthquake and was still about as muddy as the Fraser as late as July 6. Mr. Underwood states that, in the country back of Campbell River, there are many landslides. Two bridges on a road built on an old logging railroad embankment went out. A beach

disappeared in Buttle Lake, which was reported to have left a cliff 45 feet high. (Undoubtedly, this was the broken face of a slumped alluvial fan.) Mr. Underwood has furnished a report, giving details personally observed, of the damage inland in this region, which is the area designated by the second tentative location by the U. S. Coast and Geodetic Survey triangulation using the instrumental data.

(j) *Quadra Id.*

This village on Quadra Id., just across the channel from Campbell River, exists for and because of the B. C. Packers cannery. The manager reported that no damage had occurred there except for goods broken on being thrown off shelves in the store, crockery and glassware broken in houses and some chimneys injured. At the cemetery north of the village no damage of any kind could be observed on July 6.

(k) *Rebecca Spit.*

On the east side of Quadra Id. lies Drew Harbour guarded on the side by Rebecca Spit. Here, marked changes occurred in the spit and, presumably, in the water depths adjacent in the harbour. These are shown in Figs. 30, 31, 32. A diagram of the spit, copied from the British Admiralty Chart, No. 2870, is reproduced herewith. (Fig. 6).

Fig. 32 was taken with the camera facing south at the point marked D on the larger scale section of the chart. (Fig. 6.) Fig. 31 was taken from a position C on the beach, on the harbour side of the spit, with the camera facing north. Fig. 30 was taken from a point a little south-east of point B, looking along a trench about 100 yards long, cutting across the spit and having a deep sand blow near its centre. The camera was facing north-west. It is to be noted that Fig. 31 shows a series of drops toward the harbour side of the spit. All the drops which paralleled the long axis of the spit showed a drop toward this same side. This was the case, even with regard to those on the narrow neck of land at D (Fig. 32). This is in contrast to the slumps on Maple Guard Spit, which showed a drop toward both sides of the spit, as well as cross, down-dropped trenches. The series of drops shown in Fig. 31 continued to the beach and at that point the shore dropped off into deep water at once. It may be conjectured that any deepening of the waters about Rebecca Spit

is confined to Drew Harbour. As echo-soundings are believed to have been previously made in this harbour it would be of value from a scientific point of view to have new profiles made though it is believed that any changes found will be in the nature of increases in depth. As the drop on the beach totals ten or twelve feet it is possible that quite marked changes may be found in Drew Harbour.

The reply, dated August 6, reads as follows:

(1) *Read Island:*

The observations on Read Id. were made by the B. C. Police. Photographs taken by them are reproduced as Figs. 39, 40, 41, & 42. These were all taken on a farm owned by Mr. S. K. Marshall. The position of this property is indicated approximately by the X shown in the smaller scale part of the sketch map furnished herewith

(Fig. 6).

The report made by Skpt. A. E. Frost, of the Campbell River Detachment, reads, in part, as follows:

For the information of the Department, I would like to state that the damage caused by the earthquake was indeed very severe to this man's property. An area of about 12 acres was almost completely devastated. Parts of his orchard and oat field have sunk between 30 and 40 feet. This sunken area is about 250 ft. long and 150 ft. wide and part of it has formed into a small lake. Cattle are kept for several hundred yards from this sunken area into the woods. A bluish clay has been pushed up to the surface in several places.

Marshall's place is situated near Burdwood Bay, approximate Latitude 50 degrees 10 minutes North, Longitude 125 degrees 30 minutes West, Admiralty Chart 2870.

An added report by Constable MacAlpine of the Campbell River Detachment reads, in part, as follows:

(We) made a patrol to Read Id. and surveyed the damage which is beyond words to properly express and describe. Several persons were interviewed in the immediate area and all heard a very distinct rumbling noise; seconds prior to the quake, a low-lying sound, defining a low east to west. On receipt of this report and the photographs, a letter was sent to Constable MacAlpine, under date of Aug. 18, in which the following definite questions were asked:

There is one further vital point on which we should like direct information. In all these earth disturbances, was there any case of an absolute down-drop of a previously flat area? In other words, were these slumps on slopes, which slipped sideways into a ravine, gully or down-hill, or were they bounded on

all sides by slump cracks which face inward to a depression? If some of each type were found, which were the more extensive? In the photograph of the orchard, for example, it appears as though the ground is on a hillside, the surface of which slipped downward.

One other point: Your report states that a noise or rumbling was heard prior to the quake. The newspaper reports indicate that those noises have been heard as late as, say, July 25. Are those rumblings still being heard?

The reply, dated August 6, reads as follows:

In my opinion, all of the disturbances on Read Island were absolute down-drops from normally flat land. The area concerned would be called flat although there might be a slight irregularity in the surface of small knolls perhaps two or three feet in height. There was no indication whatsoever of side slip in this surface. One peculiarity is the fact that, although there are faults extending into the new-growth forest, the damage was confined to the area under cultivation.

With reference to the question on noise and rumbling, I made mention of the fact that the rumbling was heard prior to the quake, as this was general in the Read Island area. Newspaper reports of subsequent rumblings can be discredited. At no time did the patrol hear noises nor can any information be obtained of residents hearing any rumblings since the quake.

According to newspaper accounts accompanied by a picture of the conditions shown in Fig. 40, some of the "cliffs" (really faces of a down-drop) were "thirty feet high." Assuming the oats, in head, to be about two feet high, one can readily see that the down-drop near the centre of Fig. 40 might easily be as much as twenty feet. It is possible that the face was even greater in the near foreground of the same picture.

It must be concluded that the damage on Read Id. is due to a down-drop of the foundation rocks. The promontory forming the southern tip of Read Id., south of Marshall's farm, is shown as mountainous, with peaks about 600 feet high. Immediately north of the farm, the terrain is also shown as high, with peaks up to 800 feet. Burdwell Bay, on which the farm lies, forms one indentation of the east coast, defining a low-lying valley, which extends across the neck of the promontory to another long bay on the west of the promontory, opposite Burdwell Bay. It is in this valley that these marked evidences of serious earthquake action are located.

12. *Summary and Conclusions:*

One of the most severe earthquakes of which any report can be obtained, which has affected any part of Canada within historic times,

occurred along the central east coast of Vancouver Island at 10^h 13^m 19^s a.m., P.D.T., on Sunday morning, June 23, 1946. The tremors were well recorded on seismographs at all stations in North America and excellent seismological records were also obtained from a number of stations in Europe.

The epicentre, tentatively designated by the triangulation from seismograph records, is at Lat. 49°.9 N., Long. 125°.3 W., a point about ten miles S.S.W. of Campbell River. This position and also the focal time given above are subject to minor amendment when the collected seismograms are studied later at the Dominion Observatory, where they are now being assembled.

A field study of the earthquake indicates that the epicentre is not even approximately a point, but is certainly a line extending along the eastern edge of Vancouver Id. from Deep Bay, opposite the south end of Denman Id. to Campbell River, and that parts of Quadra Id. and Read Id. are also affected.

The tremors continued (at Deep Bay, for example) for about thirty seconds. As nearly as could be learned, this was the estimate of reliable observers throughout much of the main epicentral region above designated.

In addition to broken chimneys, damaged goods in stores, broken crockery and glassware, windows, etc., there were marked changes in the land, particularly at Maple Guard Spit which flanks Deep Bay, at Goose Spit and at Drew Harbour on the east side of Quadra Id. and also near Burdwood Bay on the east coast of the southern promontory of Read Id. Cracks many feet in depth and up to eighteen inches in width opened up for lengths up to several hundred feet on the sand spits. An area of flat land, fifteen to twenty acres in extent, was down-dropped in level, cultivated fields on Read Id. Some of the faces of the drops were as much as twenty to thirty feet in depth.

At many places along the coast from Deep Bay to above Campbell River, water spouts were seen, which were described in some cases as thirty feet in height. These left permanent records on the sand spits, in the form of craters or "sand blows", which varied from a few inches across to craters five feet in diameter and three feet deep, after several weeks of exposure to rain. At the time of the earthquake some of these "could not be bottomed with a twelve-foot pole".

In many places the coastal waters were found to have increased in depth just off shore, by measured amounts up to 100 feet. A beach disappeared at the west end of Comox Lake, leaving a measured water depth of 33 feet where, previously there had been a beach, well above water. No report, authenticated or otherwise, indicates any place where a rise in the ground occurred, or where marine depths were lessened, except for a long welt which appeared on the beach at Westview, on the mainland south of Powell River. It is believed that all marine depth changes will be found to be in the nature of increases.

In addition to the epicentral region of which no doubt is entertained, there is another section which may have participated in the true tectonic shock. This includes Powell River (unlikely), the Alberni Canal opposite Franklin Creek, and some inlets near the outer end of Alberni Canal (unlikely).

On the Alberni Canal opposite Franklin Creek, considerable changes in depth certainly occurred near the shore, and seem, according to some soundings made, to have been found also in the channel. More than a mile of telegraph cable was lost at this point by the C.P.R. Telegraphs. Their soundings indicated increases in depth of more than 100 feet at some points.

There were many landslides, not only in the primary and secondary epicentral regions, but on most of the lakes on Vancouver Id. and even in the Fraser Valley, more than forty miles east of Vancouver. In many cases, an alluvial fan, extending from the steep rocks bordering the shores of these lakes and resting with its submerged outer rim on the marginal shelf, slipped off into deep water, leaving a steep cliff face, sometimes as much as thirty feet or more in height, at the point where the fan broke from the shore. Local waves of some violence occurred at such points, but general "tidal waves" did not result. Seiches of moderate height were observed for some hours on many of the lakes.

One man, Capt. Daniel Fiddler, was drowned off Maple Guard Spit when his dinghy was overturned at the time of the earthquake. His body was recovered after about two weeks. An employee of the B.C. Packers' plant at Kildonan was operating an ice crusher at the time of the shock. The piles supporting the front end of the wharf slumped off into deep water and the wharf sagged. He was thrown

into the water with the crusher, but was rescued with no more serious injury than a broken shoulder. A man in Seattle is said to have died of heart failure due to the shock. In many places residents suffered minor injuries from broken glass, etc. There were no fires resulting from the earthquake.

Damage, becoming notably less with increasing distance from the epicentre, was reported throughout Vancouver Id. and adjacent territory on smaller islands and on the mainland. The tremors were felt as far south as Portland, Ore., and as far east as Kelowna in the Okanagan Valley. The point farthest north, from which a report was received indicating that anyone had felt the tremors, was Smithers, but it was not a general experience north of Ocean Falls and Bella Coola. The evidence is conclusive that this earthquake was not associated with the Queen Charlotte Ids. nor with any submarine fault off the continental shelf in the Pacific.

In general, there were few cases of rotation of chimneys or gravestones; only ten authenticated cases are recorded. Of these, all lying south and east of a line associated with maximum disturbance (up the Alberni Canal to Alberni, across the height of land to Qualicum Beach, thence through Deep Bay and up the coast to Campbell River, Quadra Id. and Read Id.) turned clockwise. All north and west of that line turned contra-clockwise. No significance can be attached to this fact, since the data are so few.

The earthquake was, in general experience, preceded and accompanied by a heavy subterranean roar. At several places, however, competent observers indicate that there was absolutely no sound until the heavy shock occurred.

Unique among earthquakes of this magnitude, only one aftershock was recorded. This was felt generally throughout the main and secondary epicentral districts but was not sufficiently strong to cause any damage. One other slight shock was reported as having been felt by three people and still another by two observing together. Except for these three light tremors, no aftershocks have been reported to the date of this writing.

Dominion Observatory,
Ottawa, Canada,

September 9, 1946.