being evidently derived from the Tairua andesitic tuffs. The masses generally present a corroded and often ropy appearance, with a pitted surface. Under the microscope it is seen to consist of a very pale-yellow glassy ground-mass, with scattered feldspars and augite, the former occurring as narrow laths and phenocrysts, apparently representing two crops of generation. The feldspar laths are arranged with their principal axes parallel to the fluxion plane. Some binary twins do not exhibit straight extinction, and cannot be sanidine. The majority of the feldspar microliths and plates appear to be plagioclase. Augite is fairly abundant, often well formed and generally twinned. Occurs both as plates and narrow laths, which lie with their long axes parallel with the fluxion plane. Polarisation colours very brilliant. One phenocryst, showing multiple twinning, encloses two crystals of feldspar. Magnetite not very abundant.

ANDESITIC GLASS, OMAHU HILL.

This is a black semi-vitreous rock speckled with white feldspars. Lustre vitreous; feels rough. It occurs as irregular masses in the grey tuffs on the Omahu Bridle-track, about a quarter of a mile on the Thames Valley side of Odlam's gold-mining claim. Under the microscope it is seen to consist of a grey glass exhibiting wavy fluxion lines, and surrounding a few large and badly developed phenocrysts of plagioclase. Some patches of the base are partially devitrified and crowded with microliths of feldspar and augite. Augite is fairly abundant. A little magnetite is dusted throughout the base.

ART. XLI.—*On the Secular Movements of the New Zealand Coast-line.*

By Professor JAMES PARK, F.G.S., Director, Otago University School of Mines.

[*Read before the Otago Institute, 12th November, 1901.*]

THE solid ground is popularly considered the symbol of stability, but exact observations in the older-peopled countries of Europe have shown that, on the contrary, the crust of the earth is in a state of constant oscillation. The upheaval or depression of the land from this secular movement is so slow and gradual as to produce no appreciable difference in the physical aspect of the ground affected from year to year, and it is only after the lapse of generations, and

by means of careful measurements, that it can be proved to exist. It is only along the coast-line, where sea-level affords an unvarying base of verification, that these tranquil movements can be detected and measured.

As early as 1730 Celsius, the Swedish astronomer, had noted the gradual rise of the Scandinavian Peninsula. In 1731, in company with Linnæus, he placed a stone mark at the base of a cliff in the Island of Loeffgrund, not far from Jefle, and thirteen years afterwards was able personally to verify that the Baltic Sea had retreated 7 in., or at the rate of 4 ft. 5 in. for a century.*

That the rate of movement is not always uniform over wide regions, but differential, is shown in the case of the Baltic shores of Scandinavia. For example, at the northern extremity of the Gulf of Bothnia, at the mouth of the Tornea, the continent is emerging from the sea at the rate of 5 ft. 3 in. in a century, but by the side of the Aland Isles the rise, according to Reclus, is only at the rate of 3 ft. 3 in. in the same time. South of the isles the rate of upheaval is even slower, and further south the ground moves so slowly as to appear quite stable even in a century. This region, indeed, seems to be the pivot of the oscillation, for further south, at Scania, the most southerly part of Sweden, the land is sinking gradually, as proved by the submergence of forests and older streets of the towns of Trelleborg, Ystad, and Malmoe. It was at Scania that Linnæus, in 1749, exactly determined the position of a stone, which was found after a lapse of eighty-seven years to be 100 ft. nearer the water's edge. According to Erdmann the subsidence at Scania has now ceased, or has been exchanged for an upward movement, but it will require observations extending over another half-century to verify this conclusion.†

Celsius and his contemporaries were impressed with the view that the emergence of the land was due to the recession of the sea, the changes in the relative level of sea and land being ascribed to variations in the form of the oceanic envelope. Most of the evidence available is adverse to this conclusion, and modern geologists and physicists alike are in favour of regarding the relative changes of land and sea as due to movements of the solid land only. The mean level of the sea is now generally regarded as a constant datum, not necessarily unvarying, but varying within such infinitesimal limits as to be practically constant as a verification datum.

The principal evidences of an elevation of the land are raised beaches, sea-worn caves at present beyond the reach of

* "The Earth," Reclus, p. 621.
† Geol. For. Stockholm Forhandl., i., p. 93.

the sea, elevated sea-ledges and terraces, human records and traditions. A subsidence of the land is more difficult to trace, as each successive sea-margin is washed away or covered over as the submergence continues. The existence of a submerged forest, of fringing coral islands, or of fiords, may be regarded as perfectly reliable evidence of subsidence. In studying the oscillations of the earth it is necessary to guard against the numerous causes of error that may arise from the unceasing struggle being waged between the land and sea. Neither the encroachment of the sea on the shore-line, which may be due to progressive erosion, nor the recession of the sea, which may be due to local accumulations of alluvial detritus, are to be accepted as evidence of subsidence without due consideration. And, since secular elevation or depression of the land is always taking place, it is obvious that an encroachment or recession of the sea, due to denudation or reclamation, may coincide with a geologic upheaval or depression. Therefore in searching for proofs of such movements the student must be on his guard against being deceived by any apparent advance or recession of the sea.

The great and varied assemblage of marine formations in New Zealand, including representatives of nearly all ages, affords ample proof that this country has been subject to many alternating upheavals and subsidences in past geological times.

In the absence of human records it is impossible to definitely or even approximately determine the direction of the present secular movements on our shores. There is abundant evidence that oscillations have taken place in comparatively recent times, but there are no data at our disposal to enable us to ascertain whether the movements which produced this evidence are still progressing in the same direction. An upward motion may be succeeded by a period of subsidence, and in the absence of a means of accurate measurement it would not be safe to generalise on the evidence of what has taken place in some past time, however recent.

The buried and submerged pine forests in the Thames Valley and Bay of Plenty prove that the movement in those regions has been downward up till a very recent date. The extent of this area of subsidence cannot be defined, but the geological evidence clearly indicates that it extended as far west as the shores of Auckland Harbour. Whether this secular subsidence of the Hauraki Gulf is still in progress cannot be determined at present.

A submerged forest on the sea-shore near Waitotara, with the trunks of the trees still standing erect in the sea, points to a very recent subsidence of the land in that region. The

well-known raised beach around Wellington Harbour was upheaved suddenly during an earthquake about forty years ago, and must not be confused with the evidences of slow secular movement.

The raised terraces on the coast-line of Canterbury and Otago, and the recent excavation of the narrow rocky gorges of the Clutha, Taieri, and other rivers draining the east side of the "great divide," point to a slow but continuous elevation of the land which may still be in progress. On the other hand, there can be little doubt that the fiords or sounds of south-west Otago were narrow mountain-glens excavated by subaerial agencies at a time when the land stood at a higher level than at present. The subsidence which has been in progress in that region since post-Tertiary times has allowed the sea to run up and fill the submerged glens. Thus each fiord will mark the site of a submerged valley.

New Zealand, from its insular position, its division by the sea into islands, its numerous harbours and extensive coast-line, is destined to become an important maritime nation. It will always be dependent on the sea for its communications and commerce, both internal and foreign, and this will necessitate the erection and maintenance of harbours, docks, and coast-protection works of a costly and permanent character, specially adapted to accommodate the trading-vessels of the future. It is quite certain that, in the design and erection of these works, the direction of the secular movements of the land will be factors demanding serious consideration. Hence it is now our duty—a duty we owe to posterity—to erect around our shores permanent marks or stones, the positions of which have been accurately determined, for the guidance of the engineers of the future. For example, an accurately determined progressive and uniform upheaval of the floor of a harbour at the rate of, say, 6 ft. in a century would necessitate the introduction of important modifications in the design of dock-accommodation intended to be of a permanent character. Further, it is well known that subsidence in an area allows the accumulation of silts, sand, and gravels in the estuaries, harbours, or rivers in that area; while, conversely, the rising of an area permits the sweeping-away and scouring-out of old accumulations of alluvial detritus in harbours and similar situations. Since the engineer is called upon to combat, or at least direct, the forces of nature, he should be provided with a full knowledge of the direction of these forces, otherwise his best-devised schemes may soon become useless, if not actually destructive.

Stone marks have long since been erected on their shores by most of the civilised maritime states of Europe and America, and the time has arrived when this should be done

here; and not only in New Zealand, but on the shores of the Commonwealth of Australia. It has been shown that the secular movements are so quiet and slow as to produce no appreciable alteration from day to day or year to year. They often require a lapse of several generations to be capable of proof by careful measurement; hence the sooner the marks are erected the earlier will the data be available in the future.

The proofs of upheaval and subsidence are sometimes obtainable over wide continental areas, but generally are marked by a local and variable character; hence, marks should be erected on the shores of all our harbours, on the headlands and outlying projections of land. The work has a high scientific and economic importance, and would naturally fall to the State Department of Lands and Surveys. It could, perhaps, be most conveniently carried on simultaneously with the magnetic survey of the colony now in progress. The marking of the coasts of Australia should be undertaken by the Federal Government, so as to obtain uniformity in the method of determining a mean sea-level datum. Up till now no serious attempt has yet been made to determine the relation of sea-level to the land in New Zealand on a scientific basis, and for this reason the marking of the coast-line with stones, whose position has been accurately determined with respect to sea-level, would further supply a much-needed datum of verification for the officers of the Lands and Survey Department for their more exact geodetic and hydrographical surveys.

Art. XLII.—*Notes on some Glacier Moraines in the Leith Valley, Dunedin.*

By Professor James Park, F.G.S., Director, Otago University School of Mines.

[*Read before the Otago Institute, 12th November, 1901.*]

Plates XXVII.–XXVIII.

The glaciers of New Zealand are reputed to be the largest in existence outside the polar regions, with perhaps the exception of some in the higher Himalayas. They are found clinging to both flanks of the "main divide" of the South Island, their greatest development being within the Province of Canterbury. On the West Coast they descend to within 750 ft. of sea-level, into the midst of the evergreen forest. On the east side, where the slope is more gradual and the