from the ordinary fish-type can be explained on teleological grounds. The enormous development of the jaws throws the branchial apparatus out of place, and entails its eventual degradation. The peculiar construction of the mouth, and opposability of the jaws, appear to be correlated with selection for food, which seems to consist principally of globigerinae and copepods, which are doubtless restrained from escape, with the water ejected from the mouth, by the structures functioning as pockets and whalebone.

Another paper, largely based on the work of the Albatross, was that of Dr. Gill on the ichthyological peculiarities of the Bassalian realm, as he has proposed to call the deep-sea region. His views, which are at direct variance from those of Dr. Günther, based on the study of the Challenger material, will be given in some detail in an early number of *Science*.

In his paper on mastodons, read by Dr. Gill, Prof. E. D. Cope claimed that ten species were known from North America, of which no less than eight flourished during the Puerco period.

Dr. J. S. Billings, through Major Powell, suggested a new method of studying crania by means of composite photography, and exhibited some very interesting prints taken in illustration, on each of which seven adults of the same race and sex were shown from in front, in profile, and from beneath. Sioux, Eskimo, and Hawaiian-Islanders were the races chosen; and the method seemed capable of wide application with good results.

President E. M. Gallaudet read a paper on the 'combined system' of teaching the deaf, which he illustrated by one of his pupils, who could answer questions put to him with considerable distinctness. The speaker was not, however, of opinion that the use of the manual system could be entirely dispensed with, and characterized as a fallacy the views supposed to be held by another school, — that because some deaf had been taught to speak by lip instruction, therefore all could be so taught. The system which Dr. Gallaudet prefers, he would probably consider an eclectic one, applying to each case the method best adapted to it.

The following gentlemen were elected members of the academy: Profs. E. S. Dana and Sydney I. Smith of Yale college, Gen. C. B. Comstock of the corps of engineers, Dr. W. K. Brooks of Johns Hopkins university, and Capt. C. E. Dutton of the U. S. geological survey.

The autumn session of the academy will be held in October, at Newport, R.I.

AN ARCTIC VESSEL AND HER EQUIPMENT.

A GOOD portion of the science of navigation is devoted to the subject of safety. In navigation in the ice, that object is increased tenfold in importance, and overshadows all others. In the history of the different arctic voyages, whether for popular reading or for scientific report, this question of safety has generally been considered only so far as that particular voyage had any thing interesting or useful to suggest as a result of its own adventures. While it is not hoped in this article to add any thing to our previous stock of knowledge, still it is possible, that by bringing together a statement of various dangers and difficulties to be met, and the methods which have been employed to overcome them, its publication will aid in an understanding of this often talked of arctic voyaging.

The subject of ice-navigation embraces the construction of ships for this peculiar employment, or the altering for it of those that have seen less severe service; their management under the various combinations of ice-packs, ice-floes, icebergs, tides, storms, currents, and every obstacle of the frigid zone; their care and preservation in the ice during the arctic winter; and their liberation from this ice when the summer will allow them to begin again their experience as they prosecute their journey on or homewards.

I will not dwell upon such indubitable facts as the quality of the ship's material, which it is evident must be of the very best, be it wood or iron, or the almost equally apparent fact of the superiority of a vessel specially constructed for this purpose, by the hands of proper persons who have had experience in arctic navigation as well as naval construction, over the reconstructed merchantman or even stronger built man-of-war. The superiority of iron ships over those of wood no longer holds in the Arctic. The rapid conductive power of the former makes it almost impossible to keep an equable temperature without a thick inside coating of some non-conductor, besides the more rapid formation of frosts from condensed moistures along the outer sides of the bunks, causing serious diseases, and greatly aiding the propagation of that most terrible of all arctic scourges, the scurvy. The superior strength and endurance of iron over wood, in the usual accidents of the temperate and tropical seas, seem to be lost when the test comes in the shape of severe pressure from the ice; the elasticity of the wood allowing it to return to its original shape after an almost indefinite number of nippings which are not sufficient to directly crush the vessel, while the same number of equal pressures on its iron companion become slowly accumulative, until it finally succumbs.

A wooden vessel, however, may be very properly plated with iron over the hull for some feet under water, to protect it from the grinding action of the 'ice-tongues,' which are formed by the unequal melting of the edges of large ice-cakes, which, projecting their huge submerged points often for a distance of twenty or thirty feet, become dangerous to a vessel compelled to thread narrow and tortuous channels and 'leads' in an open field of pack-ice, where the first intimation of their presence is a low, dull, groaning sound, and a swinging of the ship, probably a half-dozen points, despite the helmsman, or probably a perfect arrest as the helpless ship comes up broadside against the cake of ice, and with all sails thrown aback. 'Ice-tongues' which gradually shoal from a greater depth than that drawn by the vessel are not so dangerous as those not so deep, the latter acting like a ram in a collision. In case of a 'nip' or a pressure from ice on both sides, these same ice-tongues are to be earnestly prayed for, as their shoaling sides often aid a vessel in being lifted out of the water, when, in such a tremendous pressure, she could be saved in no other way. Therefore, when a 'nip' is inevitable in a narrow 'lead' constantly closing down on a vessel, this fact should be strongly borne in mind in selecting that point where the least damage will probably be done when the final collision comes. It would appear, therefore, that iron ships are inferior to their weaker but more elastic wooden compeers; and this is ably demonstrated by facts in the sad fate of the River Tay in 1868, in Baffin's Bay, and of the Swedish exploring-ship Sophia, in the north of Spitzbergen. In both instances these vessels sank under circumstances where good wooden vessels would probably have survived.

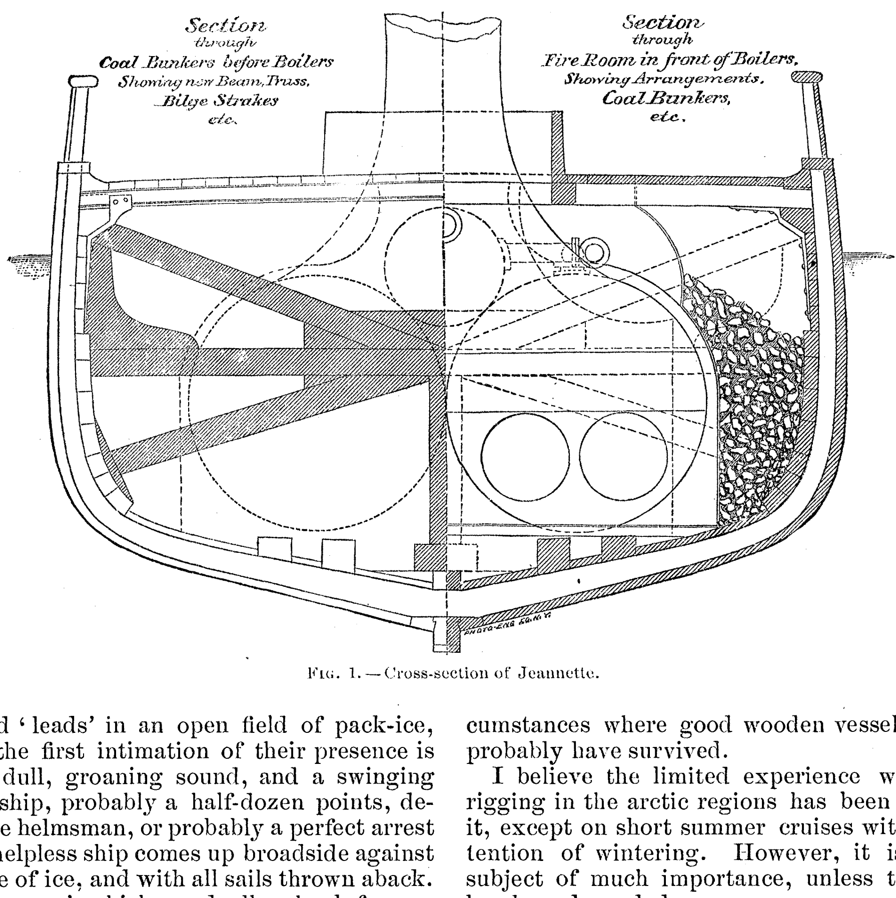

Fig. 1.—Cross-section of Jeannette.

I believe the limited experience with iron rigging in the arctic regions has been against it, except on short summer cruises with no intention of wintering. However, it is not a subject of much importance, unless the sails be alone depended on.

Coppering is of little or no use, and I have not been able to find any comments upon it by those who have used it. In such cases it was probably a part of the sheathing before the vessels were intended for arctic duty, as on the Erebus and Terror. The fact that most vessels are sheathed with two or three inches of planking in their vulnerable parts for ice-navigation, makes the ordinary metal sheathing of but little importance. This wooden sheathing varies considerably in arctic vessels as to the parts of the ships that are plated, the thickness and amount, and kinds of hard or soft wood planking.

Having decided to build a wooden vessel, the shape of the hull is not a matter of indifference. The full, round ship, or, nautically speaking, a ship with full lines, is much more liable to be crushed by ice-pressure than one built with sharp lines; as fully illustrated in Koldeway's German expedition, when the Germania, built upon the latter principle, stood the ice-nip without very serious consequences during a heavy storm, while her companion the Hansa was crushed and sunk, she being modelled upon the former plan; and this, despite the fact that the Germania was the larger vessel, and therefore more liable to destruction than her lighter escort. This was also said to be the fault with the Jeannette, whose cross-section is shown in fig. 1, taken from Mrs. De Long's 'The voyage of the Jeannette.' Nothing less than an 'ice-tongue,' whose submerged edge would be below the point braced by the inclined beam at its foot, would have been of much use to save her in a 'nip' by the method of lifting already noticed.

These 'ice-tongues' are very much less frequent than most people might suppose from the constant use of the expression in this article. They are really very rare; at least, of such shape and size as those indicated. The edges of an ice-cake or an ice-floe may be of any shape consistent with unequal melting of its parts, and the 'tongue' is only one of the rare varieties. If very acute, it may be too weak to wedge up a boat, and may break off, as I saw in one instance, which, luckily, was not caused by a 'nip,' or the ship would have been immediately crushed. It is upon the relative position of these inequalities of the ice-edge fore and aft of a ship, that depends whether or not she will inevitably be crushed when two cakes or floes come together at her position during a heavy ice-pressure: therefore, the larger the ice-cakes in a pack, the better is her chance of escape.

The ease with which a ship can be lifted is, of course, a direct function of her size and weight. The size for an arctic exploring-vessel may vary, depending upon the service to which she may be put, and the time she is to be employed in polar seas; still, the general principle that a vessel should be as small as possible, compatible with the object in view is a good one. The smaller and lighter the boat, the more easily is she raised by the squeezing floes; and the cases where this lifting of a vessel from the glacial vice, in one or two instances completely from her element, has been the salvation of her, are sufficiently numerous to be taken into account. Again: a small ship is more readily handled in the tortuous channels through which she is often compelled to thread her way while working in floes just sufficiently open to allow progress.

While arctic authorities agree upon the employment of small ships, the exact size in tons is seldom stated; but, in the few cases mentioned, about four hundred tons may be taken as the maximum limit. The superiority that a large vessel has over a smaller one in its greater momentum, when called upon to 'ram' the ice, so as to force a passage, is compensated by the fact, which experience has fully settled, that the large ship will succumb sooner to these severe and repeated shocks that she is thus compelled to bear. It should be added, that it is only when the floes are small, and the ice comparatively loose, that any ship, whatever may be her size, can 'ram' it with any fair prospect of effecting a passage. A steamer intended for 'ramming' the ice is always strengthened at the bows by 'dead-

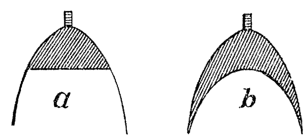

Fig. 2.—'Deadwood' backing for bows.

wood,' or a solid wood backing (Fig. 2) not unlike that given to trial-targets for ordnance practice in solidity and strength. The depth of this may reach as much as twenty feet, although I have only heard of and never seen such depth. It may be cut off abruptly perpendicular to the keel (*a*), or given a parabolic flare (*b*), which, for the same amount of wood, is evidently the stronger for the various strains that the bow of an ice-vessel may be called upon to bear.

With a vessel thus provided, sometimes a triangular indentation of a thin floe may be 'rammed,' and the ice split by the wedge, the vessel burying herself in the crack; and then, when there is a large crew, their running in a body from port to starboard, and reverse, by rocking the vessel, has been known to increase the new 'lead,' and allow the vessel to back out for further operations. When the wind is blowing vigorously, there are some disadvantages in 'ramming,' besides the condition of the pack caused by it. A vessel with the wind on the beam, and standing high out of water, and with considerable sailing-gear aloft, drifts faster than the pack, and, in backing out for a fresh start, may find the ice in the rear interfering with her backward movements; for a propeller must be very careful in all her retrograde actions.

This charging, 'ramming,' or pushing of ice by a vessel brings us to a consideration of the motive power most serviceable for ice-navigation, — steam or sails; for it is only by the former that charging can be made possible, except in those extremely attenuated packs where the headway of the sailing-craft is sufficient to carry her safely through, should she be compelled to strike a few glancing blows on isolated cakes. The use of steam may be laid down to be all-important, despite the fact that some few persons of no inconsiderable experience as arctic navigators still denounce the waste of room occupied by the steaming-machinery; the necessarily large amount of fuel to make it effective; and the anxiety imposed upon the commander regarding his propeller, which may break its blades, despite its protection of iron grating, and other derangements of machinery, that may here become extremely difficult, if not impossible, to repair. The first attempt to use steam in ice-navigation was with a paddle-wheel steamer, in 1829; and, as would be expected, it was the most worthless when the most needed. The pro-

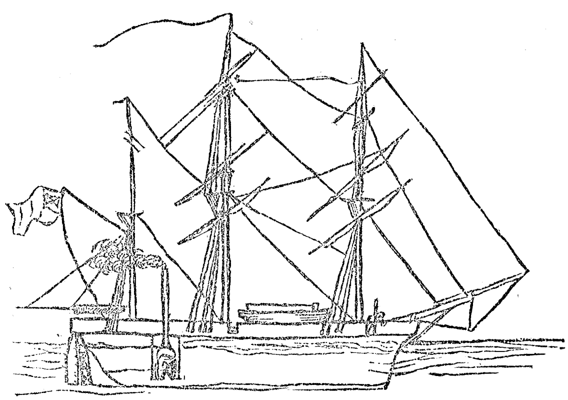

FIG. 3. — Sketch showing engines in Sir John Franklin's ships.

peller was first used on Sir John Franklin's ill-fated expedition in the Erebus and Terror, in 1845. It was worked by locomotive machinery; and how well it did its work, like a great deal of other information concerning that party, is wrapped in mystery. Certain it is, Sir John Franklin came nearer accomplishing his object than any of his predecessors; but whether due to his propellers, or to a favorable season, can only rest on conjecture. However, his propellers were not powerful enough to release him from his two-years' besetment in the ice-packs of Victoria Straits, unless the cause was due to a scarcity of coal.

With the various improvements in propellers, especially in their protection by iron gratings and baskets, came their more universal use in arctic navigation; and at this date one seldom hears of an expedition to these waters not thoroughly fitted with this most essential auxiliary to a perfect success. By steam-power only can a vessel defy the ever variable winds of those regions. The Mallory propeller, or some modification of that form, will, I think, be found useful in threading narrow lanes through ice-packs. Certain it is that there is no place in the annals of navigation where a vessel is called upon to constantly make such short turns in such limited space as in ice-navigation. Of the steam-winch placed on the Jeannette's deck forward of the smoke-stack, capable of lifting the screw, unshipping the rudder, and warping the ship ahead, De Long's journal says, "Our steam-winch did good service, for we could easily snub the ship's head into a weak place when we did not have room to turn her with the helm."

Running before a breeze and with a current is said to be the most favorable condition that can be secured for a sailing-craft, more on account of the disjointed and open condition of the ice-pack that is usually produced by this state of affairs than the speed, which should always be lowered, sailer or steamer, if there is any danger of unnecessary collision with the ice. Even in this most favorable state, if she be running towards the throat of a funnel-shaped channel, she will more than probably encounter a gorged ice-pack at this point, barring her farther progress. A sailing-vessel caught in this predicament is in a very precarious condition. To the well-known obstacles of returning against wind and current, there is superadded the incoming ice, which will certainly add one or two, if not two or three, points to her leeway, in constantly attempting to weather the large ice-cakes and often equally dense and larger ice-packs with fruitless results. The time lost in wearing her around, or throwing her on the other tack when a channel, open one minute, has closed in her front, makes it almost and often quite impossible to return: and the grinding, crushing pack soon builds up to her position, and encloses her under the most dangerous circumstances that can occur in ice-pressure, unless she can find an 'ice-dock' like that described by Dr. Kane; and even this, at any minute, is liable to be obliterated by an increase of wind, or a pressure due to the accumulation of ice or change of tide. This state of affairs is, I think, more than probably illustrated in the case of the besetment of Sir John Franklin's Erebus and Terror, in September, 1846, off Cape Felix, on King William's Land. Attempting to pass through Victoria Channel, whose southward-trending current is at this point greatly narrowed by the converging shores of Victoria Land on the west, and those of North Somerset, Boothia, and King William's Land on the east, his propellers worthless or his coal-supply short, either he must have encountered this ice-gorge so late in the year that his ships were almost immediately frozen in, or the summer's winds held him against or in the pack, as already indicated. The latter idea seems to me very reasonable; for during the time my party was on King William's Land, from the time the ice broke up in Victoria Channel on July 24, 1879, until the ice, newly forming, was sufficiently thick to stop a sailing-vessel (which was about the middle or latter part of September), I was forced to notice an almost continuous north-north-west veering to north-east wind, evidently caused by the warm rays of the almost never-setting summer's sun heating and rarifying the atmosphere over the vast snowless plains of upper British America, whose place is filled by the denser air chilled by the great ice-fields of the Arctic Ocean. That this Victoria Channel is navigable under very favorable and exceptional circumstances is shown by the fact that one of these two ships afterwards floated down or sailed through this narrow strait to near the mainland of America, some one hundred and fifty miles, manned by not more than four or five men.

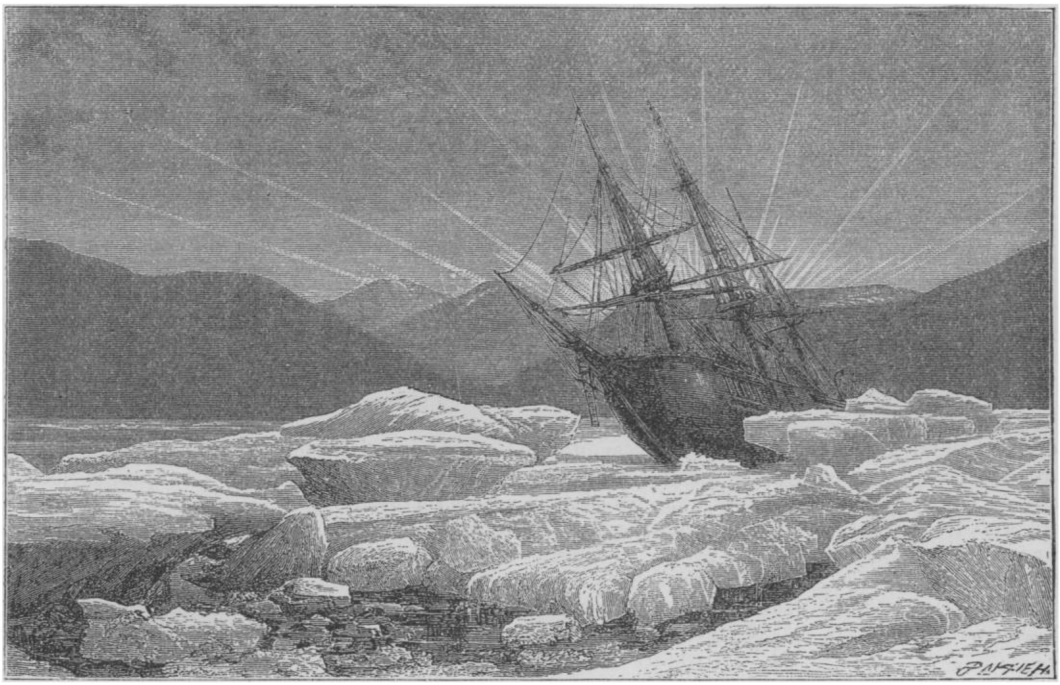

Fig. 4. — H.M.S. Alert forced on the land.

A steam-vessel can go into winter harbor much later than one with sails alone; and this is of no small importance, considering the short season during which navigation is at all practicable. This arises mostly from her superior advantages in 'charging' the newly forming ice of the early fall. The action of a sailing-vessel in this kind of ice is so well described by Sir Edward Parry, who had seen five arctic expeditions, all in sailing-craft, that I transcribe his short description: —

"The formation of young ice upon the surface of the water is the circumstance which most decidedly begins to put a stop to the navigation of these seas, and warns the seaman that his season of active operations is nearly at an end. It is indeed scarcely possible to conceive the degree of hindrance occasioned by this impediment, trifling as it always appears before it is encountered. When the sheet has acquired a thickness of about half an inch, and is of considerable extent, a ship is liable to be stopped by it unless favored by a strong and free wind; and even when still retaining her way through the water at the rate of a mile an hour, her course is not always under the control of the helmsman, though assisted by the nicest attention to the action of the sails, but depends upon some accidental increase or decrease in the thickness of the sheet of ice, with which one bow or the other comes in contact. Nor is it possible in this situation for the boats to render their usual assistance by running out lines or otherwise; for, once having entered the young ice, they can only be propelled slowly through it by digging the oars and boat-hooks through it, at the same time breaking it across the bows, and by rolling the boat from side to side. After continuing this laborious work for some time with little good effect, and considerable damage to the planks and oars, a boat is often obliged to return the same way that she came, backing out in the canal thus formed to no purpose."

A sailing-vessel caught in this unfortunate state of the ice must immediately seek winter quarters in the nearest harbor; and if that be remote, and the wind unfavorable, or, rather, unless it be extremely favorable, the crews will be forced to cut a channel the entire distance for the helpless ship. This Parry was forced to do in 1819, near Melville Island, the channel cut being nearly three miles long. On the contrary, with steam-power, ice only half an inch thick is an insignificant obstacle; and a vessel thus equipped can steadily force her way through such a thin sheet, while even that proportion of a yard can easily be overcome by charging, requiring only well-strengthened bows.

Although good arctic authority has said that "the making fast to a floe should never be attempted except when every hope of navigating in the surrounding waters has been fruitless," and further adds, "As a principle, and so far as it is possible without the exhaustion of her powers, a ship in the ice should endeavor to be in constant motion, even though this entail many changes of her course and the temporary return to a position which had been abandoned" (Payer), still the latter suggestion, involving, as it may, for a great period of time, the consumption of coal, and the many cases where vessels with banked fires have with advantage fastened to floes with their ice-anchors, ready to escape almost at a moment's notice, makes these bits of advice not strictly essential for steamers, if they be properly harbored under the lee of the ice. With a sailing-vessel, this recourse becomes much more dangerous. The fastening to an iceberg is not altogether unattended with danger, and should only be resorted to when other means of safety are remote. The Polaris was justified, in such an instance, in seizing on to Providence Berg, although I have seen some contrary opinions expressed. A sailing-vessel should only do this when it becomes necessary to avoid drifting into a more perilous position.

Another advantage of steam over sail power alone is in the case of a calm with a strong tidal or other current setting towards an ice-pack or stranded iceberg, in waters so deep that anchors are of no avail; the salvation of the latter from possible severe injuries depending upon the relative power of the current, and the strength exerted by her small boats to tow her off, while the easy escape of the former is obvious. Also, in the early and late navigation of these waters, the sails are liable to become completely clogged with ice and sleet, rendering them, in extreme cases, impossible of manipulation. This state of affairs nearly proved fatal to the Griper (Capt. Lyon, R.N.) in September, 1824, in North Hudson's Bay, while attempting to battle with a terrible two-days' storm; the sleet forming over a foot thick on her decks, and proportionally over other parts of the vessel.

I should not have entered into so long a discussion on the seemingly palpable superiority of steam-power over that of sails, were it not for the fact that such a great proportion of the arctic expeditions are of a private nature, wherein the means of the liberal donor or donors cannot reach the increased expense of steam-machinery, fuel, and its accompanying charges; and those serving are willing to accept the situation rather than compromise the expedition altogether. There are also a few, as I have already hinted, who are opposed to steam-power from the great room it sacrifices, and its liability to incur greater risks than it can escape from if at all unfortunate. There is also a medium class, who, acknowledging the waste of room as the only detriment to be found in steam, believe that this power should be represented by machinery of the cheapest class, which can be abandoned and its room made useful at any time that it fails to subserve some good purpose.

It may be laid down as a good rule, that all sailing-vessels should have some 'square' rig to subserve active movements in the ice. Sailer or steamer, the pipes for pumping should be much more capacious than usual, and there should be a system of them reaching to every part of the vessel; for the pumps may be needed the most when the vessel is careened on her beam, or at some unusual angle fore and aft.

If possible, a tender should accompany the exploring-vessel proper, especially if she be a steamer, whose stores of coal and other articles are to be transferred when the ice becomes dangerous for such a craft, presumably not strengthened to combat with that element.

FREDERICK SCHWATKA.

ON THE FUNDAMENTAL THEORY OF DYNAMIC GEOLOGY.

MANY lines of inductive research lead to the conclusion that the interior of the earth is in a fluid condition, and that the solid shell is comparatively very thin, but variable in its thickness from district to district, and in the same district from time to time geologically. A crust twenty-five miles in thickness at a maximum, and very much thinner at a minimum, best explains geologic phenomena. If we consider this crust to be made up of units defined at the upper surface by districts of some magnitude, it seems necessary to regard it as existing in a state of floating equilibrium; so that, if some portion of the rocky material is taken from any such district, it rises, and the district on which it is deposited subsides. In case material is transferred for a very short distance, appreciable displacement may not result, the local structural rigidity being sufficient to withstand, or largely withstand, the stress. But if the short transferrence is across the line of a fault, from the upraised to the thrown side, the facts seem to show that the upheaved side continues to rise by reason of unloading, and the thrown side to subside by reason of increased load.

The rigidity of the crust of the earth arising from the molecular cohesion of the solid state is greatly modified by mechanical structure. The crust is composed of geologic formations of diverse origin, diversely arranged. The formations are broken into great blocks by great fault and flexure planes, in many cases doubtless extending quite through the crust. It is also fractured in multitudinous ways, and the crevices filled with vein matter. Again: each block or segment of a faulted formation is divided into small fragments by stratum planes, joints, schist planes, and slaty cleavage. The rigidity of each minute fragment is due to the molecular cohesion of solidity, but the general rigidity of the crust is dependent on mechanical structure. The fragments of which the crust of the earth is composed are exceedingly minute when compared with geologic formations, and they appear relatively as but grains of sand when compared with the whole crust of the earth.

This fragmental character of the crust is exhibited at the surface, and to the greatest depths to which observation has extended; and, so far as it depends upon the great faults, it must extend quite through the crust. There may be and probably is a zone beneath, so nearly fluid by reason of temperature and pressure, that fractures are less easily generated and more easily repaired, but the rigidity of the crust is not increased thereby.

The solidity of the crust of the earth is limited by temperature and pressure under conditions of chemical constitution and hydration, and is further limited by the conditions of its mechanical structure.

If vertical stress be applied to a point on the surface of the earth, the strain is propagated laterally by the condition of rigidity, but not indefinitely, as this rigidity speedily vanishes in the presence of the enormous forces involved in the weight of the crust itself, and in the great bodies of matter that are unloaded and loaded at the surface. The distance to which the strain extends is greatly lessened by the fact that the crust is not a continuous solid by cohesion, but preserves continuous rigidity in a very imperfect way by mechanical structure alone.

If the crust of the earth were practically homogeneous in the specific gravity of its materials, its static equilibrium would not permit the existence of any great elevations at the surface; but to the conclusion of a general equilibrium, geologists and geodesists are alike converging; and, if true, it necessitates the further conclusion that the crust, and perhaps to some extent the underlying fluid matter, is of varying density from region to region. This conclusion follows from a consideration of the inequalities of altitude existing in the earth's surface: and, since they are ever changing from district to district, — as one subsides and another rises, — contraction and expansion must occur. The necessity for the hypothesis of contraction and expansion is not obviated by the hypothesis of a fluid interior, nor is the latter rendered unnecessary by the former.

There is a constant lateral transferrence of material at the surface by rains, rivers, and marine currents; there is a constant vertical transferrence of material by displacement; there is a constant transferrence of material