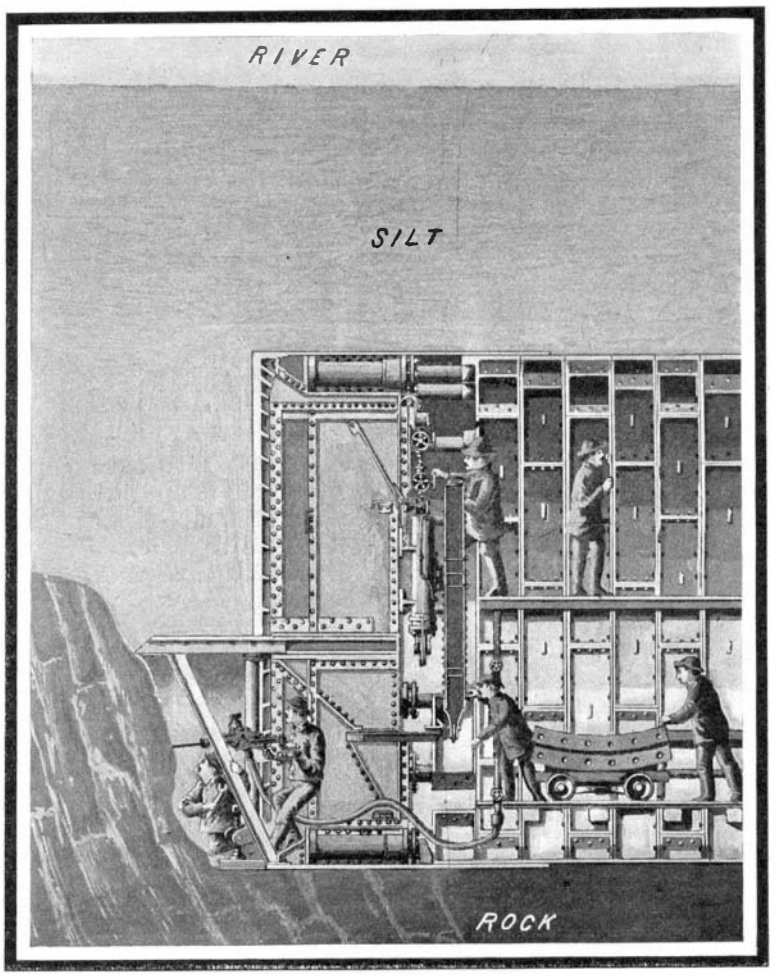
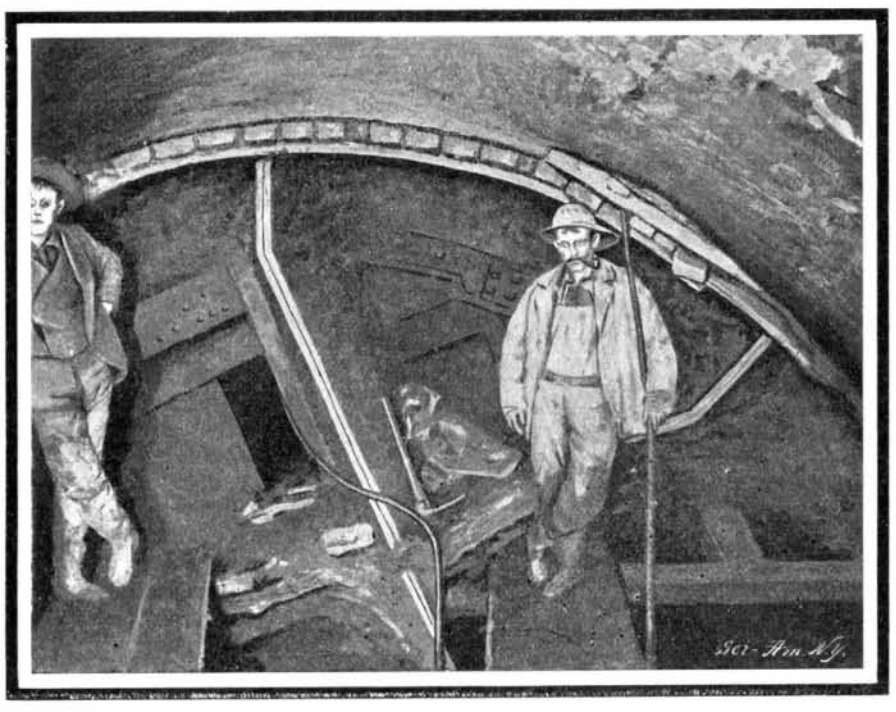
### THE HUDSON RIVER TUNNEL.

March 11, 1904, marks the successful culmination of the work begun thirty years ago on the Hudson River tunnel. On that day the junction was made between the New Jersey heading and the old New York section of the north tube and Mr. William G. McAdoo, president of the New York and New Jersey Company, was accorded the honor of being the first man to pass from Jersey City to New York under the Hudson River. The progress of this tunnel from its inception up to the present time has been periodically chronicled in these columns, so that our readers will not need a lengthy account of the undertaking, but a brief *résume* of the principal events which mark the history of this great engineering enterprise may be in order.

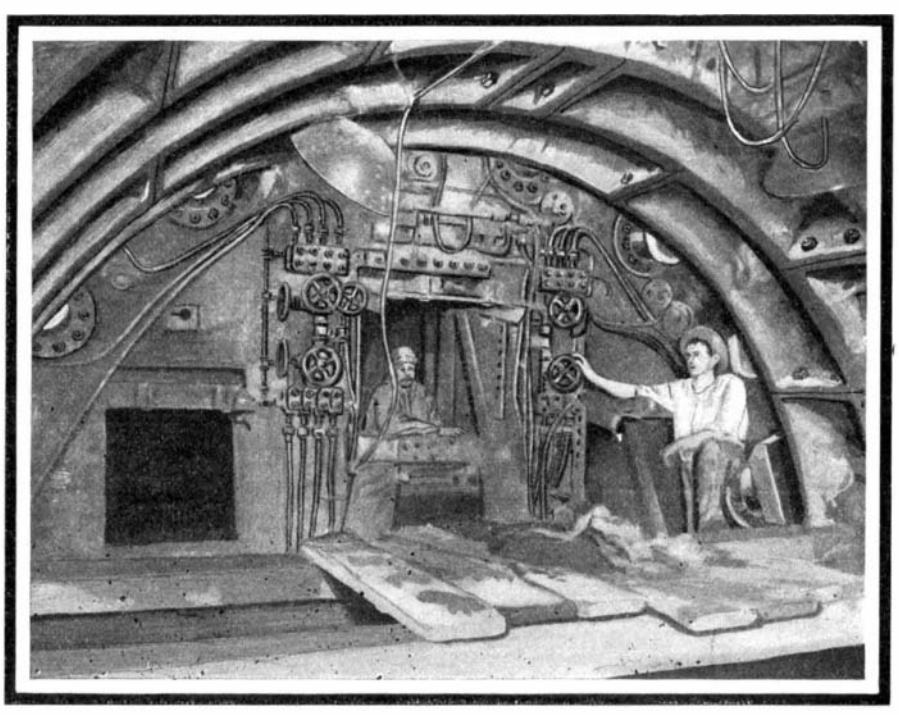
The original projector of the tunnel was Mr. Dewitt Clinton Haskin, under whose direction the work was begun in 1874. A shaft was sunk at Fifteenth Street, Jersey City, and at the foot of Morton Street, New York, and from the bottoms of these shafts twin tunnels were run out under the river. In carrying out this work no excavating shield was used, as it was thought that the silt was sufficiently compact to hold its position until the two-foot brick lining was set in place. This surmise proved incorrect, and it was found necessary to use a five-foot pilot tube, which was pushed ahead of the main tunnel and used as a center for radial braces, which supported the tunnel wall under construction. The work was carried on without serious accident until in July, 1880, the shallow layer of silt between the tunnel roof and the river gave way under the pneumatic pressure in the tunnel, and the inrushing water drowned twenty of the workmen. The work was then continued half-heartedly for two years, when, with 2,000 feet of the north tunnel completed, it was abandoned. In 1890 an English company took up the work, using an excavating shield, and working from the Jersey end carried the tunnel forward to within 1,500 feet of the old New York heading. Again the work was abandoned until 1896, when the New York and New Jersey Company took charge of the work, and in 1902 began the work which has since been carried out to its present successful issue. This magnificent engineering achievement of Jacobs and Davies, engineers of the New York and New Jersey Company, in accomplishing that which had twice before been attempted and abandoned, is deserving of highest praise, particularly in view of the fact that difficulties were met and successfully overcome, which the other companies did not encounter and which, in fact, the engineering world has never before been called upon to master. The work had progressed only a few hundred feet when rock was encountered in the lower part of the tunnel. The excavating shield in use, the one that the English company had installed, was designed to be forced through silt, and it would merely have crumpled into a shapeless mass if it had been forced against this rock barrier. It was necessary, therefore, for the workmen to advance beyond the cutting edge of the shield, and blast out this rock before moving the shield forward. If the rock had covered the entire face of the shield, this would have been a comparatively easy matter; but the engineers were confronted by the unique problem of driving the floor of the tunnel through rock and the roof through silt. To meet these conditions, it was found necessary to build an apron out in front of the shield, which would protect the workmen from the silt above. This apron, as shown in one of our illustrations, extended from side to side of the tunnel shield near its center line, and projected forward about 6 feet. It was built of ¾-inch steel plates laid on brackets formed of 12-inch I-beams. This apron enabled the workmen to attack the rock without fear of being smothered by an avalanche of the soft silt above. Even with



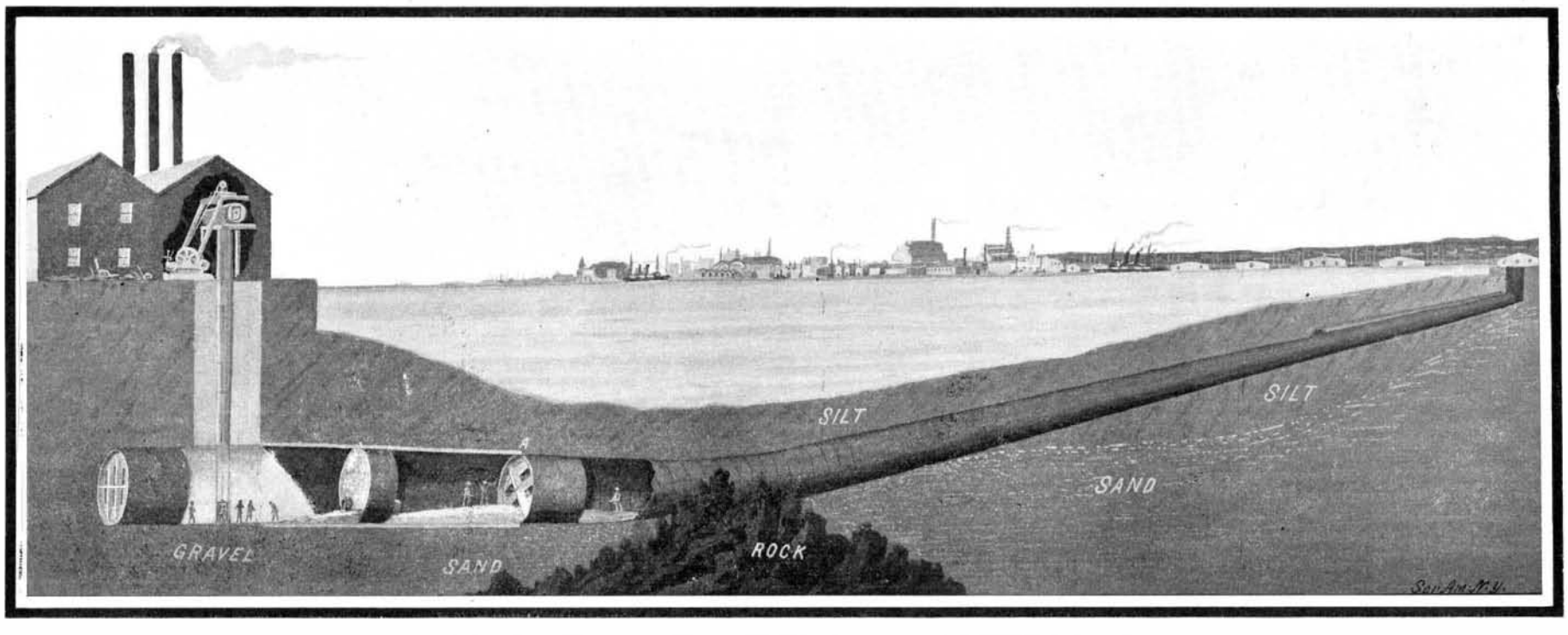

Blasting Out Rock Under the Protecting Apron.



Junction of the Two Sections, Showing Also the Tilted Position of the Shield.



The New Shield at Morton Street, Which is to Continue the Tunnel Under the City.



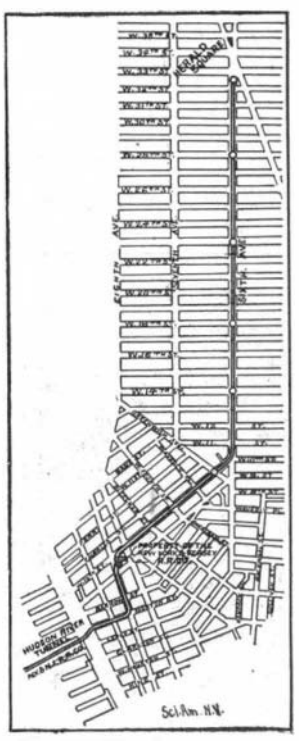

Sectional View, Showing the Course of the Tunnel Under the Hudson River.

THE HUDSON RIVER TUNNEL.

this protection the work was not without danger, as the rock varied in height from 1 to 16 feet. Fortunately, no casualties resulted, and the passage was slowly but steadily forced through the rock reef. With this danger past, the remainder of the work was comparatively simple, and the tunnel was rapidly pushed on to the New York heading.

As the work advanced, the course of the tunnel was carefully plotted out, and the excavating shield was steered by increased pressure in one or another of the hydraulic jacks, in order that it should be brought into perfect register with the brick lining of the New York heading at the point of juncture. So careful were these calculations, that when the shield met this heading, the lateral alinement was found to be almost perfect; but vertically, an error of a few inches was made. This break is temporarily sealed with blocks of wood driven into the silt above the shield, as shown in one of our photographs.

While the shield was being operated by the English company, it was noticed that instead of remaining stationary on its axis, it was gradually turning clockwise as viewed from the front. Every effort was made to stop this movement; but it continued, until now, having traversed 3,400 feet of silt, it presents the appearance illustrated, with the vertical plates lying almost horizontal. This curious action was probably due to a slight deflection of the plates in front of the diaphragm of the shield, which tended to turn the shield through an imperceptible angle every time it was jacked forward, and these slight deflections gradually accumulated until they became quite noticeable. The tunnel has an internal diameter of 18 feet 1½ inches, and is lined with cast-iron segments 1½ inches thick, braced with webs and formed with inwardly-projecting flanges, which provide means for firmly bolting the sections together. At present a pressure of 22 pounds per square inch above normal is still maintained in the greater part of the tunnel, to prevent water from seeping through the joints of the lining, which have not yet been calked up. The shield must now be dismantled, and the cast-iron sheathing or lining run out to join the brick lining of the old heading. The shell of the shield, however, cannot be removed, and will be buried behind the cast-iron lining, a final sacrifice to the work it has served so long and faithfully.



**Proposed Extension of the Hudson River Tunnel.**

Some further work remains to be done on this tunnel before it will be finally completed. The English company, in order to save the cost of cartage, spread the silt, as it was excavated, over the floor of the completed section, and as a consequence a large part of the tunnel on the Jersey side is more than half filled with this material, and it must all be removed before the work of laying car tracks can be commenced.

The south tunnel, which is being run parallel to the completed tunnel, is also being excavated from the New Jersey side, and is now well under way. A distance of three-quarters of a mile remains yet to be tunneled. A new shield was built for this work, and in anticipation of the difficulties encountered in the north tube, it was provided with an apron, which can be moved out in front of the shield to permit blasting out rock in front of the cutting edge.

We illustrate herewith a new shield, now in position, which will continue the north tunnel through the city under Morton Street and Ninth Avenue to Tenth Street, where the New York station is to be built. The course of this tunnel, together with the proposed extension, is shown in the accompanying map. The purpose is to continue the tunnel up Tenth Street to Sixth Avenue, and thence up to Herald Square, with intermediate stations at Greenwich, Fourteenth, Eighteenth, Twenty-third, and Twenty-eighth Streets.

These tunnels are intended only for the use of electric cars, and not, according to the popular misapprehension, for heavy railway trains. It is the opinion of the engineers that the silt foundation is too soft to permit the passage of heavy weights through the tunnel. The silt, though very compact under the weight of the water above, nevertheless has the properties of a viscous fluid, and it is feared that it would yield under the impact and weight of a heavy steam or electric locomotive. Such yielding, though but little, would place a tremendous bending strain on the cast-iron lining, above that it could bear, and ever so slight a rupture would result in dire consequences.

A combined elevator and air lock is in use at the head of the New York shaft. The elevator shaft ends in an air lock at its upper end, and the circular platform of the cage, when in its highest position, completely closes the mouth of the shaft, and forms the bottom of the air lock. As the compressed air is released from the lock, this platform is forced snugly in place, making an air-tight closure. The cable by which the elevator is suspended must, of course, pass through the top of the air lock, and to prevent leakage of the compressed air it is incased in a long stuffing box. The movement of the cable through this stuffing box is so slow as not to seriously wear the packing.

## THE ABRUZZI POLAR EXPEDITION.—I.

(*Continued from page* 252.)

crossed to the highest latitude. Besides attempting to reach the highest possible latitude, the expedition was also calculated to take observations on gravitation and terrestrial magnetism, and also to enlarge our meteorological and hydrographical knowledge of the localities which were to be visited and to collect as much information as possible with regard to the flora and fauna of Franz Josef Land.

Dogs are undeniably the most useful animals for man in his Polar expeditions where sledges must be dragged over the ice of the Polar Sea. They have this advantage also, that, unlike horses and reindeer, they readily eat their fellows. Their weight is small, and they can be easily carried on light boats or on ice floes. As the Danish government has forbidden the exportation of dogs from Greenland, it was decided to bring them from Western Siberia, and an order was given in July, 1898, for one hundred and twenty dogs.

The vessel selected was a whaler about to start for the seal fishery. The "Jason" as she was called, could carry 570 tons of cargo, was 131 feet long, 30 feet 6 inches wide, and drew about 16 feet. Her engines were of 60 nominal horse power and gave a speed of from 6 to 7 miles an hour. The ship had a new boiler and carried a spare propeller and rudder. Many changes were required to be made. Stanchions were placed in the hold, the lower deck, which is movable in a sealer, was firmly fixed, the masts were changed, and the vessel was transformed from a bark to a barkentine. As the object of the expedition was to reach that spot on the surface of the earth near the zenith of which shines a star, known to all from the man of learning to the peasant, what name could have been more appropriate to the ship than "Stella Polare"? So the "Jason" became the "Polar Star." The expedition consisted of His Royal Highness the Duke of the Abruzzi, Capt. Cagni, Lieut. Querini, Dr. Molinelli, Capt. Evanson, who navigated the vessel, three officers, four Alpine guides, and eight sailors. The expedition took with it supplies for four years and a preference was given to those kinds of food which had been chosen by Nansen for the first expedition of the "Fram," and Sverdrup had chosen for the second. As much variety as possible was aimed at in the choice of the supplies, so as to avoid tiring the palate. Food was divided into cases of 55 pounds each, containing the same variety, so that the contents would be accurately known at all times. Plenty of furs, coats, and woolen garments were taken. Special attention was given to caps, gloves, gauntlets, stockings, and shoes, so that all conditions of weather could be met. Stoves, tents, sledges, dog harness and firearms were also liberally provided, and 440 pounds of gun-cotton for blasting the ice were also taken. Great care was taken in the selection of the scientific instruments. Four balloons were provided, of varying shapes. Two of them were selected for actual use in the expedition. They were packed in crates to allow the air to circulate and were placed on deck along with the apparatus for producing hydrogen gas, and a small boiler. Thirty-six iron tanks containing about twelve tons of sulphuric acid were placed in the center of the deck in an inclosure lined with lead and provided with a gutter so as to prevent the acid from burning the boards of the deck in case of leakage. Six tons of iron filings completed the aeronautical outfit.

The "Polar Star" left Christiania on June 12, 1899, and Archangel was reached on June 30, where the dogs were embarked. Two rows of cages, one above the other, were built against the bulwarks of the ship on both sides. The first row rested on the deck, the other was one yard above it, and these cages were separated by wooden partitions. Four dogs were placed in each and chained to the corners so that they could not bite each other. As the cages and their floors were covered with gratings and tarpaulin, they could be frequently washed and the dogs were kept dry. The final departure of the expedition occurred on July 12 and three days later they met ice for the first time, and on July 20, the misty outlines of Northbrook Island were sighted; the Emperor Franz Josef archipelago lay before them, and the huts left by Jackson's expedition were discerned. Provisions for eight months and five tons of coal were landed, so that in case of any misfortune to the ship which would necessitate a retreat these stores would enable the explorers to subsist until the following summer. Various observations were made and on July 26 the trip was resumed. On August 5 a vessel was sighted and there was little question that this was the "Capella." The "Polar Star" signaled to know if the Wellman expedition was on board. A launch in which a man who had the appearance of an invalid was lying, with one leg stretched out, left the "Capella" and went toward the "Polar Star." Although very dissimilar from the photographs which the Duke had seen in the newspapers, he recognized Wellman. The latter was lifted on board and he was helped into the saloon. Other members of his party accompanied him. It seems that Wellman had met with an accident shortly before arriving, so that the expedition was forced to return, as it had lost some of its provisions when pressed by the ice floes and it had reached its highest latitude near the above-mentioned island. After a few pleasant hours the two ships sailed away, the "Capella" steering southward to return to civilization, while the "Polar Star" steered for Maria Elizabeth Island. On August 7, Prince Rudolph Island was reached, the latitude being 82 deg. 4 min. The "Polar Star" thus reached with the greatest ease the Emperor Franz Josef archipelago, which in 1873 Payer had thought so difficult to approach. The expedition disembarked in the Bay of Teplitz and its members immediately set to work to prepare the winter quarters. Kennels were built for the dogs, which showed little affection and still less obedience. They fear only the whip and water; for in the intensely cold regions where they live, if they get wet, the water freezes immediately on their bodies and forms a cuirass which hinders every movement. The ice field driven by the pack closed up the channel made by the "Polar Star," heeling her over about thirteen feet. The ship was righted by means of some gun-cotton mines which had been sprung on the left side, but the vessel did not remain long in normal position, as the ice again succeeded in heeling her over. The ice field in the bay driven by the ice pack had risen all around over that which lay along the coast and had reached up to the kennels, against the door of which some large floes had been piled up, thus preventing egress. When the dogs gave the alarm the crew ran to extricate them by breaking the inner partitions and letting them out on the side of the land. The vessel had also sprung a leak. There was grave danger that if the ice gave way the boat would sink, and, therefore, they were obliged to land with the utmost haste the stores for winter, and to secure the necessary materials for building a dwelling house. The outlook of a winter passed in this bay, with but scanty resources, and of a retreat to be carried out with still more scanty resources in the following spring, was gloomy. It was hard to work on board as the ship heeled over so much and the deck was covered with ice. Disembarkation continued all that day with the exception of intervals for meals. As the ship still remained in the same situation, which had not become more dangerous, and as all that was required to pass the winter had been rescued, they began to disembark what would be wanted for the sledge expedition, so that if the vessel was lost they would still have the means of accomplishing the undertaking for which they had set out. The heeling over of the vessel had rendered life on board uncomfortable, and any further pressure of the ice might have cast her on her beam ends and obliged the expedition to abandon her completely. It was therefore decided that it was better to leave her and take up land quarters where they would be safe from any sudden danger. The expedition had been provided with two field tents which would lodge the whole crew, though they alone would not suffice to protect them during the winter, or to resist the violence of the wind, but were strengthened with additional covers, also of canvas, so as to form air spaces between them, so that a sufficiently high temperature could be kept up inside, and, if the outer covering were made of stronger sail cloth, it would be able to resist the wind. The canvas awning which had stood on the deck, with the poles and cross-bars which formed its framework, was well suited to stand over the field tents. With the spars and the sails of the ship the third tent was constructed which covered the others.

(*To be concluded.*)

Newton's law of gravitation, which states that two bodies attract each other with a force inversely proportional to the square of the distance between them, has been made the subject of an exhaustive investigation by Prof. Brown, of Haverford College, says the Iron Age. He announces that his calculations show Newton's law to represent the motion of our moon to within the one-millionth part of one per cent, and states that no other physical law has ever been expressed with anything like the precision of the simple statement of this one.