

Sir Lowthian Bell, unless indeed a grateful country, which was deriving the benefit of cheap salt, would be willing to pay an extra price for it. Mr. Allhusen appeared to be in some doubt as to whether the correct mode had been adopted of ascertaining the quantity of salt worked out of the hole which had been lost. The calculation was not such a difficult one. There was a hole, which might be considered to be the centre of the apex of the cone with 100 feet of salt at the bottom. At a distance of 60 yards it was found that a certain quantity of salt had been removed. With these two factors it was easy to ascertain the quantity of salt worked out, which was found to correspond within 1,000 or 2,000 tons of the actual quantity. It was to be hoped that the whitestone, which had a thickness of 4 or 5 feet, was the point beyond which no stone fell. But unquestionably if many acres were excavated, and that rock, however strong it might be, was left unsupported, it would give way. Still he thought that the probability was that if large fragments fell in the manner he had spoken of, they would be found to interlock each other, and that the subsidence of the surface would not be a matter of such serious importance as was feared. He believed that no plan of working salt with economy, irrespective of the first cost of a shaft, could compete with that which was at present being pursued. The estimate for sinking a pit down to the salt had been variously put at from £100,000 to £200,000, an expenditure that no one felt inclined to encounter in order to obtain an article which at the time was selling in Cheshire for 5s. or 6s. a ton.

Correspondence.

Professor Hull. Professor EDWARD HULL remarked that the Author was doubtless correct in stating that the Magnesian Limestone, and the New Red Sandstone were unconformable to the Carboniferous beds: and there could be little question but that the former passed transgressively over the upturned edges of the Coal Measures on to the Millstone Grit, so that the Durham coal basin terminated along the southern concealed margin by a sharp uprise toward the north of the Millstone Grit below the Magnesian Limestone. Some years ago, he came to the conclusion that the southern limit of the Coal Measures might be taken along a line to be drawn from Heighington to Hartlepool, or Seaton Carew.¹ On the extremely

¹ "The Coal-fields of Great Britain." By Edward Hull, 4th edit. p. 272. This was the line indicated on the map of this district; and was also pointed out by Sir A. C. Ramsay in 1868, in his evidence before the Royal Commission relating to Coal in the United Kingdom.

important question whether, by means of an anticlinal as suggested Professor Hull. by the Author of the Paper, or by faulting, the Coal Measures might be supposed to set in again along the Estuary of the Tees, he could only state his impression that such an inference was scarcely warranted by the relations of the strata between Richmond and Barnard Castle, where the Millstone Grit and the Yoredale series emerged from beneath the New Red Sandstone. Over the whole of this district the strata consisted of beds older than the coal arranged in a series of east and west flexures, which passed eastwards below the New Red Sandstone and Magnesian Limestone. There was one point, however, in favour of the view, namely, that the axes themselves appeared to have a very gentle inclination towards the east, which, if continuous, might ultimately bring in the Coal Measures towards the Estuary of the Tees; on this account it might be well worth while to continue the bore-hole at the Clarence Ironworks below the Magnesian Limestone. The salt-rock under Middlesbrough seemed to occupy the exact geological position of that in Cheshire, Staffordshire, Warwickshire, and at Carrickfergus, near Belfast, being at the base of the New Red Marl (Keuper division of the Trias), and above the New Red Sandstone (Bunter). Some years ago, he had an opportunity of examining the cores of the boring at Messrs. Bolckow, Vaughan and Co.'s works, which convinced him of this fact. The beds consisted of laminated marls, shales, and thin sandstones, and were extremely yielding and pliable. The beds of salt were never found to crop out to the surface in the British Isles, as the marginal portions had been invariably dissolved away by percolating waters. It was not improbable that the rock-salt of the Middlesbrough district originally cropped out under the River Tees, and this might have had something to do with the original formation of the channel. The fact above stated might also account for the thinning out of the rock-salt at the first borings of the Newcastle Chemical Works, as the original outcrop might be supposed to have run from the Tees Valley at Stockton towards Yarm and Great Smeaton. It was evident from the boring by Messrs. Bolckow, Vaughan and Co., near their Eston Works, that the salt-bed extended in full thickness in an easterly and southerly direction, and had probably a wide extension under the Lias formation and the oolite of the Cleveland Hills. The ultimate effect of the dissolution of the rock-salt in modifying the surface of the ground (as pointed out by the Author) was a subject which might call for very serious consideration at a period not far distant. As he had already stated, the strata between the rock-salt and the surface,

Professor Hull. consisting of Lias and Keuper Marls, were exceedingly friable. The bed of sandstone referred to by the Author as lying immediately above the rock-salt, being "interstratified with marls," afforded no effectual safeguard against unequal subsidence; and the danger was still further enhanced by the cavities in the form of an inverted cone which were left after the salt had been carried away in solution. Were this process of solution to be effected by a gradual lowering of the surface of the salt-beds equably over the whole area, the danger from subsidence would be lessened, if not wholly avoided; but from the account of the Author, this appeared not to be the case, and in process of time it seemed probable that the bed of rock-salt would be pitted all over by a series of hollows in the form of inverted cones, with which the surface must in some degree ultimately conform. Considering the number and the enormous size of the furnaces, engine-houses, and other works erected over this great manufacturing district, it would be apparent that if the salt manufacture was carried on in their immediate neighbourhood, their stability would be seriously threatened. The effects being produced on the surface and buildings of the Cheshire salt-district afforded an example of what might ultimately result from the salt manufacture by the solvent process, and the first indications of undermining ought to be very carefully watched.

Mr. Ward. MR. THOMAS WARD observed that the Middlesbrough salt-deposit was interesting, as lying at a greater depth than any other at present known in this country. It was interesting also as being the only deposit worked in a way similar to the rock-salt at Nancy and the neighbourhood, and in Wurtemberg. In the Wyoming Valley, New York State, a large deposit of salt had been recently discovered of about the same thickness, but lying even deeper than the South Durham deposit. The York Salt Company in Wyoming Valley struck salt 40 feet thick at a depth of 850 feet below the surface; while the Castile Salt Company did not reach it till 2,527 feet had been bored through, when a bed 80 feet thick was found. Another peculiarity common to these deep-lying salt-beds was the absence of a natural brine. When the salt lay in a basin, as in Cheshire, natural brine was generally found; but when, as in the Middlesbrough district, the salt rested as it were upon a slope, or had a considerable dip, natural brine rarely occurred. At Middlesbrough it seemed that the rock-salt was dry when discovered, or, as was said in Cheshire, there was a "dry rock head." It was interesting to learn that the Middlesbrough salt was in the Triassic formation, like all the other salt in this country; at one

time it was thought to be in the Permian rocks. The Paper did Mr. Ward. not clearly point out where the fresh water came from that passed down the annulus. He believed at first it was conveyed from a distance and poured down; this seemed borne out by a reference to vegetable matter in the water afterwards causing a film to form on the brine, or, in common parlance, causing the pan to "set over." Later, the quantity of water in the sandstone, passed through before reaching the salt, had been found sufficient. In time, as in other districts, the accumulated store of water in the sandstone would be much diminished, and supplies from a distance must be brought and poured down, or there would be, what frequently happened in Cheshire at the end of a busy season, a great scarcity of brine. As the manufacture of salt was much the same in all parts of the world where a fully, or nearly fully, saturated brine was obtained, he need say nothing about it. He was glad the Author had touched upon two serious questions connected with the working of the South Durham salt-bed; he referred to the subsidence of land caused by brine-pumping, and the abstraction of brine belonging to one owner by another owner's pump. The Cheshire salt-beds, lying much nearer to the surface, and having been worked, and brine pumped, for a long period, the evils referred to had been felt most seriously. Middlesbrough at present only suffered destruction of bore-holes by the falling marls which occurred over the salt. He had pointed out in 1883, in a Paper read before the Manchester Literary and Philosophical Society, "On the Action of Water upon Beds of Rock-Salt,"¹ that ultimately Middlesbrough would suffer from pumping brine. The abstraction of thousands of tons of salt, without any support being left for the overlying rocks, must result in subsidence, and the longer it was deferred, the more serious it would eventually be. In Cheshire the earth frequently followed the decreasing salt-bed, and a subsidence was at once evident on the surface, and serious injury to property occurred. At other times, when the marls were thick and tenacious, they held up for a time; then a sudden and extensive fall followed, and a large hole was left, which became filled with water. At Nancy, the salt being near the surface, subsidence was not long in following brine-pumping, carried on as at Middlesbrough. In Wurtemberg, a thick bed of Muschelkalk overlaid the salt, and prevented subsidence for a considerable time. At Middlesbrough the thick bed of sandstone might remain sus-

¹ Proceedings of the Manchester Literary and Philosophical Society, vol. xxiii. p. 5.

Mr. Ward. pended for a long time over the huge cavity caused by the abstraction of salt, but eventually the bearing would be too great to allow it to stand firm, and serious subsidence must happen. The destruction of so many bore-holes told of the mischief happening below. Many centuries elapsed in Cheshire before perceptible subsidence occurred, but this was owing to the small quantity of salt made. When, however, the make reached what it was at present at Middlesbrough, subsidence became apparent, and had continued and increased ever since, until now it was very formidable. He was glad the Author pointed out what might eventually prove as great an injustice as happened daily in Cheshire. By introducing water down a bore-hole, and then starting a pump and abstracting the water again as soon as it was saturated by the surrounding salt, it was easy for the owner of a small piece of land to abstract the mineral of his neighbours as well as his own; and if this went on long, and subsidence extended to the surface, not only would the mineral be taken without leave or compensation, but the property on the surface would be seriously injured or destroyed. There was no legal remedy for this great injustice, for, unfortunately, where there were a number of pumping centres in the same district, it was impossible to say which pump caused any particular injury. He should like to point out another thing against which provision should be made at Middlesbrough; he meant the allowing brine to be pumped and sent out of the district by means of pipes. If this were permitted, the salt district might suffer all the injury caused by subsidence, without having at present any remedy, and without deriving the advantages that would accrue from the manufacture of salt or alkali in the district. It was not possible at present to say what injury would be done to the Cheshire salt trade by the Middlesbrough manufacture, but it was evident that, as pointed out by the Author, the chemical industry on the Tyne would derive its salt from South Durham. The salt was so near Middlesbrough, that the cost of carriage incurred by manufacturers in Cheshire in getting the salt to the ships was saved, and thus South Durham had an advantage over Cheshire.