Chapter 39 Water supply

The water supply of Anglesey, though partly derived from superficial, is derived in the main from subterranean sources. Four of the towns possess organised water-works, those of Llangefni and Menai Bridge being fed from springs, those of Holyhead and Beaumaris partly from springs and partly from lakes. Superficial sources being really a matter of engineering, the subterranean alone will be considered in this chapter. But over the greater part of the Island the structures are seldom sufficiently simple for the positions of water bearing beds to be stated with confidence, conditions which readily lend themselves to the mystery-mongering that, flourishes only in the realm of the unknown. Greater perplexities with regard to the behaviour of underground water could hardly be found, indeed, than those presented by the older formations, especially by the Mona Complex.

The Mona Complex

In this great formation the complexities are fourfold. Not only are time structures excessively involved, and the number of different rock-types great and varied, but there are the effects of metamorphism to be considered; in addition to which the Complex is traversed by hundreds of dykes, which, though of much later dates, must, in regard to the behaviour of water, be treated as though they were part of the Complex itself. A subject so perilous might well have been passed over with no remark save to point out its perplexities and pit-falls. Nevertheless, in view of the fact that some two-thirds of the Island are composed of this Complex, it seemed better not to omit all attempt at systematic treatment of its water problem. But the reader is requested to hear in mind that this is merely a pioneer attempt, intended to open out a way for others.

Water-content — A large proportion, perhaps more than a half, of the Complex consists of rocks that were originally sandstones, and must then have been porous. But they have been intensely compressed, while not only their matrix but in varying degrees even their sand-grains, have undergone re-crystallisation: processes which must in all cases have greatly impaired, and in many have totally destroyed their porosity. To what degree that may have survived can be determined with satisfaction only by experiment. The old shale-partings, now largely converted into closely matted secondary mica, must be quite as impervious as ever. As for the Plutonic Intrusions, or such totally re-crystallised products a the Gneisses and the various components of the Penmynydd Zone, particularly the glaucophane-schist with its high degree of density; no one would expect them to be capable of containing water intra-texturally. The Complex, in fact, might well have been expected to be, for all practical purposes, waterless.

Yet there can be no doubt that, whatever be the modes, it does contain considerable quantities of water. Innumerable springs issue from it, some of which have been successfully made use of as important sources of supply. For example, the older reservoirs of Holyhead are fed from springs in the Stack Moor Beds. The Llangefni waterworks are fed wholly, and those of Beaumaris partly, from springs in the Gwna Mélange, those of Menai Bridge from springs that rise in Gwna Green-schist that has become hardly less crystalline than the mica-schist of the adjacent Penmynydd Zone of metamorphism. A boring has lately been made about a mile to the west-north-west of Amlwch Church, which, after passing through 11½ feet of, boulder-clay, was carried down 124½ feet into the Lynas division of the Amlwch Beds. It has yielded 95,000 gallons in 24 hours, the water-surface remaining at a depth of 40 feet, and the quality being described as pure. Aberffraw gets a sufficient though unorganised supply from Gwna Green-schist that is in much the same crystalline condition. Llaufawr house obtains all that it needs from a well (worked by a wind-pump) that has been sunk in the Soldiers' Point Beds. Llys Dulas and Bryn-fuches obtain 60 gallons an hour from springs that are thrown out along Post-Ordovician ruptures traversing the Gneisses, from which rocks the water must therefore be derived. Rhiwlas is adequately supplied from a seven-foot well (worked by wind-pump) in the Gwna (general) Mélange; and Lianfairynghornwy Schoolhouse from a spring that rises from the same beds about 300 feet above the Carmel Head Thrust-plane. Two shafts, about 50 and 30 feet deep respectively, sunk in Gwna phyllite-and-grit mélange, give a good supply to Bodorgan house; and one about 20 feet deep in the same rock supplies Bethel village. Other villages, as well as numerous isolated farms and houses, obtain water from scattered springs that rise in various other sub-divisions.

Modes of retention — The foregoing examples leave no doubt of the presence of a water-content in the Mona Complex. In what modes, then, is it contained? To some extent, as we shall see, it would appear to be intra-textural; but there is good evidence that it is for the most part fissural, for springs issue even from the glaucophane-schist and the very heart of the Coedana granite, where it cannot possibly be held within the body of the rock. Now the accessible parts of the Complex are far from being in the sound and firmly-welded state in which they left the metamorphic forge. The disruptive movements of successive ages (pp. 201, 536–60) have riddled them with innumerable fissures and capillary channels. In some parts these may be met with at intervals of no more than a few inches, and almost all of them show signs of having been traversed by atmospheric waters. At saturation-level, the content of rocks in this condition, however impervious their texture, must be considerable, and there can be no doubt that most of the waters of the Complex on the main Island are contained in this manner. But some of the more massive sandy beds, especially on the low tectonic horizons that emerge in Holy Isle, which are regularly folded, are nothing like so shattered, whence it would seem as if some at any rate of their water is intra-textural, though, in view of the crystallisation, this calls for further investigation.

The necessity of exploration — The fact that the Complex as a whole contains water does not, however, preclude the possibility of large waterless tracts within it; and there is little doubt that such exist. Experimental exploration, consequently, remains as much a necessity as ever. Our information, so far, is derived from springs and wells, with only two borings that have reached 100 feet. The object of the succeeding paragraphs will be to point out certain principles in the light of which it will be possible to systematise such exploration and direct it to the elucidation of definite problems.

The distribution of the content — If such be the modes of water-content, what are its modes of distribution? On the negative side, certain portions of the Complex may be turned away from as probably waterless. Holy Isle, whatever be its intra-textural water, is unlikely to contain much fissural, and the southern part of the Western Region very little more. Nothing is to be looked for from dense and massive rocks like the Church Bay Tuffs, the Holyhead and Gwna quartzites, and the hornfelses, or from the pelitic though fissile Celyn beds. Of the major members of the Complex, the most unpromising is the Penmynydd Zone of Metamorphism, which is due to the fact that, in it, old fissuring has been obliterated by crystalline re-cementation. Its mica-schist, after having been pierced for 110 feet, was rightly abandoned by the engineers of the Sub-Carboniferous boring at Plâs-newydd (p. 658, and Chapter 41).

On the positive side, the question is largely one of the distribution of fissuring, whose degree of development, which varies greatly, will be a measure of content. The trend of the fissures will obviously determine the direction of water-movement, but they will usually appear at first sight to be utterly chaotic. Attentive scrutiny, however, will reveal some relation between them and the dominant ruptures of the district, relations, therefore, to be studied in connexion with each particular case, for no general rule can be laid down. Fissuring, however, strange to say, is not without a stratigraphical distribution. For owing to their heterogeneous nature, combined with certain tectonic accidents (pp. 193–5), the Gwna Beds are peculiarly susceptible to it; and we have just seen that in seven cases quoted they have been successfully drawn upon for water. They may, in fact, be regarded as a kind of water-bearing horizon, the best that is known in the Mona Complex. Moreover, in the Western and Northern Regions they rest upon the comparatively impervious Church Bay Tuffs, and in the Middle and Aethwy Regions upon the re-cemented rocks of the Penmynydd Zone which, being less fissurable, must tend to raise their saturation-level. Owing also to the very circumstance that led us to regard them as a kind of water-bearing horizon, they are repeatedly found in the cores of major secondary synclines, wherein their water may be expected to concentrate on artesian principles. Any water that may possibly be intra-textural is, of course, to be looked for chiefly in massive grits like those of the Stack Moor beds, and will tend to be held up by the micaceous partings, concentrating where these curve down into the minor infolds, and travelling along such infolds as they plunge down the pitch. Further, as the South Stack Series follows' upon the Celyn beds, which must be nearly impermeable, their water may be expected (where the succession is not inverted) to concentrate in the major infolds.

Favourable tracts and lines — Just as water is apt to concentrate at the junction of a porous with an impervious rock, so may it be expected at the junction of a fracturable and a tenacious one. This is seen where the Coedana granite, which has been severely fractured, comes against any of its hornfels products, springs repeatedly rising at or near the contact. Springs are also frequent along late faults, which have shattered the structures, and water was found on a line of this kind near Menai Bridge. The best lines of all, however, will be those where either faults- or dykes cut sharply across the strike of the Complex, intercepting water that is passing along it. Excellent examples of this principle are the North

Stack, Namarch, and Hell's Mouth faults, the Holyhead, Rhoscolyn, Bodior, Capel-mawr, and Felin-bach dykes, along all of which springs are thrown out. Specially favourable are those faults which throw down a highly fissured group against a tougher and denser one. A conspicuous case is that of the Hell's Mouth fault, which, cutting the strike at about 70°, brings down the Gwna Beds against the Church Bay Tuffs, and throws out, accordingly, a line of powerful springs. Where the beds on the downthrow side are folded, and the folding pitches towards the fault, all the most favourable conditions are combined. Such a combination we find where the North Stack fault crosses Holyhead Mountain. Cutting across the strike at about 85°, it brings down the sandy Stack Moor beds against the dense mass of the Holyhead Quartzite. The Stack Moor beds, taken in on the Stack Moor major syncline, are also thrown into numberless minor folds, the whole of which folding pitches towards the fault. At this fault, accordingly, the springs rise that feed the reservoirs of Holyhead water-works.

Quality— Most of the waters from the Mona Complex will be tolerably free from dissolved mineral matter, with the exception of iron, which has been found in some of them, and is derived from the broken-down rock of the planes of crushing, which has been rendered chemically unstable. That from the Gwna Beds varies a good deal according to the members of the group that are locally present. It has usually been found to be somewhat calcareous, and when there are considerable masses of limestone will of course be decidedly 'hard', with probably also a good deal of magnesium, though most of the 'hardness' will be of the 'temporary' kind that is removable by boiling. It may be hard even where no limestone can be seen, since, owing to the lenticular form of the beds (see below), they may thin out all round underground, and have no outcrop. Several cases of this kind have been proved.

Penetrability of rocks — Attention ought, perhaps, to be called to the fact that (except the limestones, the serpentines, and some of the more fissile schists) the rocks of the Mona Complex possess a high, some of them (such as the quartzites) an extremely high degree of durability. In such rocks boring must be costly. Choice of site should therefore be largely dictated by penetrability. There are districts where a few yards in one direction or another, while making little or no difference to the water obtained, would very seriously affect the cost of the undertaking. It inay also be remarked that some of the rocks (such as the Gneisses) are, locally, very much decomposed at time surface, and appear, therefore, to be quite easily penetrable. But this is merely a phenomenon of the superficial zone of weathering, and the same rock, at a depth of 40 or 50 feet, might prove to be thoroughly sound, and very difficult to penetrate.

Deceptive structures — A few of the bearings upon water-problems of the structural complexity alluded to above may be pointed out, in order that the difficulties of the subject may be realised. First of these are the extraordinary inversions of the recumbent folding. For example, a boring through the Llwyn beds at Rhoscolyn would, on the western side of the fault, pass down into the Celyn beds, but on the other side of the fault, perhaps only a few yards away, into the Stack Moor beds! The secondary folding may even reverse the inversion, and restore, locally, the normal order of superposition! Thrusts, imperceptible as features, may cut out large parts of the succession, as at Tre-Arddur and about Bodorgan. The condition of the Gwna Beds is of especial importance, for, having yielded water in a number of cases, they are sure to be explored for it. As a result of the excessive disruption they have undergone (pp. 65–6, 193–5, &c.), the subterranean continuity of any visible bed is rarely to be relied upon. Conversely, beds may be met with underground which never reach the surface; some of such buried masses, now revealed by the work of the sea, being visible (p. 309) on the lofty cliffs of Gynfor, while an inland example is quoted on p. 296. Now, suppose that a boring, begun in the more penetrable members of the group, should encounter a hidden lenticular mass of the quartzite. Nothing but a costly experiment could throw light on its magnitude or its relations. It might be tolerably thin, and therefore, if the dip wore low, present but a moderate obstacle. But if the dip were high, or if a low surface-dip should have curved underground to a steep or even vertical one, then the boring might have in front of it several hundred feet of a barren rock of almost impenetrable hardness.

Recapitulation — Sufficient evidence has now been adduced to show that the Mona Complex is far from being waterless, that the Gwna Beds in particular may be regarded as a water-bearing horizon, and that favourable conditions may be looked for along certain lines. On the other hand, several members of the Complex are likely to be barren, while its structures are extremely involved, and frequently deceptive. It must be clearly understood that success, even where most probable, cannot be predicted; and that those who are compelled to seek for water in this formation must be prepared to face the possibility of failure.

The Ordovician and associated rocks

Difficulties due to structural complexity are again serious in these formations, though vastly less so than in the Mona Complex, while such as arise from alteration of the rocks are for the most part effects of the compression that has induced the slaty cleavage. With regard to the characters of the rocks themselves, we need not doubt that, before compression, the sandstones and conglomerates were porous and hydriferous; while it is clear that the shales, as such, must be impervious. What degree of porosity may have survived the compression and chloritisation of the grits is not yet known. In the Rhosneigr boring, the cleaved shale proved to be quite waterless, but a little water came in as the thin courses of grit were passed through. In the broad central parts of the Principal Area, therefore, where cleavage is feeble and sometimes absent, the thick basal grit may be expected to retain some of its porosity. The shales will be easy to penetrate, but the basal grits are hard. The Palieozoic Intrusions ought to be avoided in any case.

Structural considerations — The basal grit would be accessible to artesian sinkings in the shallowest of the isoclinal infolds (such as those about Bryn-gwallen), where only the lowest graptolite zone is present, but where higher zones appear the depth of shale would be too great. Water may also be expected at the base of the grit, where it rests upon the Mona Complex. The Ffynnon Gybi, near Llanerchymedd, celebrated in the ancient legend that has been retold by Matthew Arnold, issues precisely at this junction, at a spot where a small fault, releasing the water from the high dip, allows it to escape in the direction of the strike.

Structural complications may cause disappointment. When the Rhosneigr boring was resolved upon, this had been duly pointed out, but it was decided, in view of a permanent burden of expense attached to the only alternative plan, to take the risks of an artesian sinking to the basal grit.. There seemed a hope that the synclinal infold might be tolerably symmetrical, without severe thrusting on the obscure north-western side. Had that been the case, the base of the shale would have been reached at an easily accessible depth. It was not reached at 600 feet, showing that the thrust along the north-western limb was much greater than was then to be expected. Fossils (though long sought for) had not at that time been obtained at Rhosneigr. Those that have since been found (p. 440) reveal that both of the Arenig and even one of the Llanvirn zones may be present. In the light of this knowledge, the prospect of a great depth of shale would have been apparent, and the risk would probably never have been taken. Whenever, therefore, any deep or expensive sinking in the Ordovician rocks is contemplated, all evidence (especially fossil evidence) as to the local structures must be carefully considered, in order that every source of possible failure may be realised.

In another way, however, the disturbances have been beneficial. Mr. Prichard states that Llwydiarth Esgob obtains a plentiful supply of water from wells (six to 30 feet in depth) all of which are in the black shales, the town of Llanerchymedd, and the Workhouse, being supplied from wells (six to ten feet deep), also in the shales, here belonging to the lower zones. We know, moreover, that the early miners at Parys Mountain, sinking in the Silurian shale near the east end of the infold, were greatly troubled by waters. Now, all these shales are far too impervious to contain water intra-texturally, whence it follows that the supply must (like the fissural waters of the Mona Complex) be derived from capillary channels (p. 576) that have been produced along the numerous minor thrusts. Throughout the Ordovician areas, it may be well to remark, no sinkings should be made where there is any sign of spilositic alteration (pp. 493, 531, 533) for this indicates that hidden sills of hard igneous rock will be encountered under such places.

Characters of the waters — All the dark shales are ferruginous, and the state of combination of their iron (p. 413) makes it almost certain that their water will take it into solution as $FeSO_4$, so that they may be expected to be chalybeate in varying degrees, which Mr. Prichard writes is the case with all those about Llwydiarth Esgob. In the vicinity of any of the ironstones (p. 407) this will of course be intensified.

The Old Red Series

The fine dust-rocks of the lower member are probably impervious; but the upper member, being largely sandstone, may be sufficiently porous to contain some water, unless the compression that induced the cleavage has been too powerful. The best positions are probably in the Penrhoslligwy syncline, where there are several springs that seem to be thrown out along minor fractures parallel to the Lligwy fault. 'Hardness' is to be expected, as, even in -the upper division of the series there are a good many cornstones.

The Carboniferous rocks

Structure is now simple, but there are a good many uncertainties, most of which are due to the impersistence of many of the beds. The limestones will be easy to penetrate, while the Plâs Newydd boring and those in the Coal-field afford plenty of experience from which to estimate the cost of water-sinkings in any other member of the series.

The Limestone Series

The limestones — The massive limestones are certain to be open along the joints and even cavernous to a considerable depth, so that the higher ground may be expected to be waterless. Lord Boston kindly permits me to quote the typical example of Lligwy, 200 feet above the sea, where a system of rain-water tanks has to be employed. The Lligwy limestones are some way up in the D2 sub-zone, and, so it is probable that water can descend well into the D1 sub-zone, through more than 100 feet of beds, before meeting with any check. The shales must be impervious, but they are very thin and impersistent save in the groups of dark flaggy limestone (p. 604, Type No. 3). Springs at the outcrop of such a group may be seen at Moryn, Porth-y-forllwyd, where there is a thicker shale than usual. Borings, accordingly, have a good prospect of success where such a group underlies massive limestones.

The sandstones are porous, and undoubtedly of water-bearing types, but as almost all of them rest upon limestone, their water will usually descend below them as far as the general level of rock-saturation, unless the underlying limestone belong to one of the Type-3 groups, with frequent bands of shale. The Cadarn and Caban sandstones rest upon just such a group, and it is noteworthy that their outcrops are extremely boggy, which is doubtless due to their contained water being held up, so that borings in them, if sufficiently above their base, would probably be successful. The impersistence of the sandstones, however, must be carefully allowed for in every case, for all except two (winch will be considered below) are known to thin out rapidly. There is good evidence (p. 642) that even the Cadarn and Caban group, with an aggregate thickness at its outcrop of 220 feet, thins out altogether underground between Llyn Cadarn and the Berw fault. Its absence or attenuation will affect all water-sinkings of any depth in the Llanbedr-goch and Llanddyfnan country, a tract of some six square miles in extent. The two favourable exceptions alluded to are the Lligwy and Fanogle sandstones. Being at the base of the Carboniferous series, they are not underlain by limestone; while both are of considerable thickness, and do not thin out with the rapidity of the higher ones. They dip at low angles, and the outcrops of both of them are for the most part well above sea-level. The Fanogle sandstone, owing to faulting, is barely visible at the surface except in Plâs Newydd Park, but there is evidence that it persists for some miles to the west. It may be thinning, but borings through the lower beds of the limestone, if within 200 yards of the Braint fault, are tolerably sure to tap it as far as Trefwri, and probably for a mile or so beyond. A recent boring in it (p. 638) yielded 1,000 gallons a day. The Lligwy sandstone is full of springs, and, where its outcrop is above the 200-foot contour, is probably the best source of underground water in the Island.

Tectonical considerations — The Carboniferous areas are (pp. 678–83, &c.) traversed by numerous faults, along which many springs, including the famous Wishing Well of Penmon, are thrown out. Now, where a sandstone or one of the shaley groups is dipping towards a fault, at which it is cut off, a sinking down to it at some point near the fault would probably yield a supply. But the base of the water-bearing bed, if underlain by massive limestone, should not be pierced. An excellent example of these conditions is found at Porthamel Hall, whose spring (which Lord Boston tells me has never been known to fail) rises precisely where the Carnedd sandstone is (p. 651) cut off against the Porthamel fault. Along the axis of the Red Wharf syncline, artesian wells are likely to be successful even in the limestone, but still more if the Cadarn and Caban sandstones be tapped. In view, however, of the south-eastward attenuation of these beds underground, the position must not be too near the Berw faults. A north-east and south-west line running through Llanddyfnan Church and Talwrn would seem to offer a prospect of not missing those beds, combined with the structural advantages of a low part of the synclinal infold.

Characters of the waters — Water derived from the limestones, and also from the sandstones where pierced through an overlying limestone, will of course be calcareous, and consequently 'hard', though the 'hardness' will be of the temporary' kind which is largely removable by boiling. That of wells which are sunk in sandstone outcrops may be tolerably soft, save in those cases where limestone lumps are present in the rock. The Lligwy and Fanogle sandstones (except at the top of the former, where they are, locally, abundant) appear to be tolerably free from such lumps. The following analysis of water from a spring (shown on the six-inch maps) that rises about the middle of the Lligwy sandstone, at a spot near the road across the common, 590 yards east by north from Penrhoslligwy Church, is kindly supplied by Lord Boston:

		Grains per Imperial Gallon
Solid Constituents		10.92
Chiefly $CaCO_3$ and $CaSO_4$, but including NaCl	0.322	
Oxidisable Organic Matter	0.224	
Actual (Saline) Ammonia		0.001
Organic (Albuminoid) Ammonia		0.002
Hardness in Clarke's Scale = 7°		

When the water is allowed to stand for a little while, $Fe_2(HO)_6$ comes down as a reddish precipitate. Anal. A. Voelcker, Lab. Roy. Agric. Soc., England, Jan. 8, 1881.

The water is therefore tolerably 'soft'. Had the proportion of $CaCO_3$ to $CaSO_4$ been given, the degree of 'permanent hardness' due to the latter could have been estimated. It is a pity that the proportion of $Fe_2(HO)_6$ (presumably included in the 'solid constituents'), and the combination in which the iron is held in solution, are not stated, for on the six-inch maps the spring is described as 'chalybeate'.

Upper Carboniferous rocks

The Millstone Grit has the aspect of a water-bearing rock, though it may really be less pervious than it seems, on account of the remarkable kaolinite matrix. It rests, indeed (save at Bodorgan) upon limestone, which, however, is comparatively thin, and probably below saturation-level' where sinkings are likely to be made. On the other hand, the old mines of Trefdraeth must rob it of a good deal of its water. That the Coal Measures, with most of the Red Measures of the Malldraeth, are thoroughly water-logged is evident from the flooding of the mines. But they are unfavourably situated, and probably subject to various contaminations. The Red Measure marls at Foel Ferry are probably waterless, but water-bearing sandstones of the same formation, let down by faulting and therefore concealed, are not unlikely to lie below them.

The Glacial and later superficial deposits

The Glacial sands and gravels, resting upon boulder-clay, are sure to contain water, and where they are sufficiently thick and extensive, wells may be sunk in them. Some of the smaller gravel-patches may be really emergences of the intercalated group, and if there be good reason for suspecting this to be the case, it may possibly be worth while to make a few trials round about the exposure, in hopes of an exten sion of the gravel beneath the upper boulder-clay, though no very wide extensions are to be looked for.

Much more water has been obtained from wells in the boulder-clays themselves than might have been expected. No doubt this is partly due to hidden gravels of the intercalated group, for there is always great difficulty in ascertaining the real nature of the deposits that were pierced. A good deal of water, however, undoubtedly finds its way between the boulder-clay and the underlying rock. This may often be seen along the sea-cliffs, while a 33-foot well at Llandegfan (p. 762) began to fill as soon as it struck the rocky floor. Where they rest upon sandstones, or upon the quartzose rocks of the Mona Complex, the boulder-clays are often somewhat sandy, those of the Eastern Margin being generally so, no matter what rock they rest upon. Such clays cannot be wholly impervious; and where the rocky floor, instead of being striated, has been shattered, the breccia would also be tolerably pervious. In districts of this kind, accordingly, some supply may be expected at the base of the glacial deposits. Most of the shallow little wells of the rural districts are probably fed in some such ways as these.

The quality is likely to vary with the composition of the drifts themselves (p. 708). That which emerges on the sea-cliffs is frequently ferruginous, occasionally so much so as to deposit thin seams of limonite, so chalybeate waters may be met with inland as well.

The great Blown Sands of the west, which may be 50 feet thick in places, contain a good deal of water in their lower beds, and as they rest for the most part upon boulder-clay, this water is held up, springs coming out where the sand is blown away or swept thin. In the dunes of Newborough there are a number of such springs, some of them breaking out at the foot of a rampart or cirque of high dunes, even though the base of the sand is not laid bare at the place.

The supply from any of the Glacial or later deposits, however, would be liable to dwindle considerably in hot summers. Finally, whatever be the rock which any water-sinking is intended to tap, the thickness and the nature of the local Glacial drifts ought always to be taken into consideration before the sinking is begun.

Borings near boundaries

When a boring of any depth is contemplated anywhere near the junction of two geological formations, the nature of the bounding-plane is matter of the first importance. Many springs rise along the Berw and other great boundary faults. The plane of junction in such cases is at a high angle, and a few yards in this direction or that may determine whether the boring will be on a waterless or a water-bearing side of the fault. When the junction-plane is at a low angle, borings near it will speedily pass down into a formation that may be totally different from that in which it starts. In the case of the Llangoed boring (p. 432–3) the nature of the shales into which it would pass, and the depth at which they would be reached could have been predicted with ease. That the Plâs Newydd boring (p. 658) would, after a while, penetrate the Mona Complex was certain, and the depth at which it would reach the base of the sandstone and pass into the Complex, if calculated from the data supplied on the six-inch maps, will be found to differ by about a dozen feet from the result of the experiment itself. Among the older rocks of the Island, owing to their extraordinary disturbances, borings near junctions may pass down through older into younger formations. At short distances to the north of the Carmel Head thrust-plane, for example, after penetrating 100 feet or thereabouts of hard crystalline schists, they would usually pass down into soft black shale of the Ordovician series. Water, therefore, is likely to be held up on the sole of this thrust, at whose outcrop, indeed, many springs issue.

Pollution

In a country such as Anglesey, whose water supply is almost entirely from subterranean sources, the dangers of pollution are as insidious as they are serious, and call for careful study. Pollution has been proved to be capable, under certain circumstances, of traversing hundreds of feet of rock, and of travelling for considerable distances. Underground, moreover, owing to the restricted supply of even free oxygen, the lack of ozone, of sunlight, and of humic bacteria, dangerous organisms escape the destruction which would overtake them in the course of an open-air journey. Limestone districts, accordingly, need especial attention, owing to the labyrinthine system of fissures and caverns by which that rock is apt to be penetrated. Experiments, made with colouring-matters, in the Carboniferous Limestone of West Yorkshire and the Mendips, have made it possible to identify emerging waters, and have revealed the surprising length of their underground courses. Similar experiments, with a view to detecting the direction from which pollution could come in, ought to be made in Anglesey before water-schemes in its limestone districts are embarked upon. In the Ordovician rocks and the Mona Complex, the tracts lying in the directions from which the dip-arrows, either of bedding, foliation, or folding-pitch point, should be inspected; and protraction of the dip-angle will often indicate an area wherein special care should be taken to exclude all sources of pollution.

The form of the sub-glacial surface may have bearings upon sanitation. The boulder-clays fill (and mask) many sub-glacial hollows that are nearly, if not quite, rock-basins. Water finding its way down as above suggested (p. 873) would escape from such hollows but very slowly, and might become nearly stagnant between the drift and the rock. If it brought with it organic matter from human habitations it might become extremely unwholesome. There is reason to suspect a coincidence between conditions of this kind and certain curiously persistent local recurrences of cancer. The subject may be worth investigation in connection with that and other diseases whose causes are as yet but imperfectly understood.

Pollution may also travel horizontally along fault-planes, and an inspection of the map will show that several burial grounds in the Island are situated within a few yards of powerful faults. We may hope for a time when the practice of cremation, general in ancient G-rmco-Roman Europe, and still general in further Asia, will once more supersede the insanitary and repulsive custom of earth-burial; but that time has not arrived, and is likely to be a long way off in rural districts. Until it comes, the position of burial grounds in relation to subterranean water-courses will have to be taken into consideration.

Inorganic poisons — The foregoing remarks refer to pollution by organic matter, but it should also be remembered that waters from any sources adjacent to the metasomatic centres described in Chapters 19, 36, and 37, ought to be avoided, or at any rate very carefully analysed. For they will be likely to contain traces of copper and other metallic salts, which are not only poisonous when in considerable quantity, but tend, even when present only in minute proportions, to accumulate slowly in the human system. Traces also of arsenic may be present in some of them.

General remarks

It will be seen from the foregoing evidence that Anglesey contains considerable natural resources of underground water. But it will also be seen that (save in the tolerably simple case of the Carboniferous rocks) very grave perplexities attend the question of its distribution and behaviour. For the works at Holyhead and Beaumaris, the difficulties have been partly evaded by making use of superficial sources. But for villages and isolated houses, they can hardly be evaded in that way. The risks must be faced, though by a careful study of each particular case they can be considerably reduced. Further, no data should ever be lost. Records of all water sinkings in the Island (*with full detail of the waterless as well as of the water-bearing rocks passed through*), and of all available analyses, ought to be deposited in some public place; besides which, the cores brought up from all borings ought to be carefully preserved within buildings, to guard them from decay. If these records, analyses, and cores be studied by local water-engineers *who have previously studied, and mastered, the geological principles,* there is little doubt that the water-problem of Anglesey will eventually be solved.