OBSERVATIONS ON THE ORIGIN AND EFFECTS OF THE INDUSTRIAL DUSTS OF EAST ANTRIM

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GEOLOGICAL SCIENCE is responsible for the location of mineral resources, from which are derived end-products that determine the material standards of comfort and wealth in a civilised society. Every facet of technological achievement is totally dependent on raw materials wrested from the Earth's crust. Unfortunately few who partake of the benefits are aware of the origin from which they emanate. This is a regrettable deficiency, particularly in Antrim, which has the richest geological heritage of any county in the British Isles.

The industries on the Antrim coastal strip are compact, modest in scope and output, nevertheless it has been possible to note the effects by inhalation of a variety of dusts on the human organism. The results observed do not invariably correspond with those already published in the literature. It is obviously as desirable to recognise substances that are innocuous, as it is necessary to be aware of the few that represent a serious respiratory hazard if inhaled. Some knowledge of the composition and evolution of the parent rock is necessary for a complete understanding of pathogenic dusts when these present, therefore a brief geological note precedes discussion on the ore or mineral concerned.

LIMESTONE

Limestone contain microscopic traces of belemnites, brachiopods, and other marine exuvia indicative of an era millions of years ago, when Ireland was submerged under the sea, and trillions of these creatures multiplied prodigiously in the warm waters. Their shells and skeletons, pulverised by the action of the waves drifted down to carpet the primeval ocean bed (Lawlor, 1928), to a depth of thousands of feet (Carson, 1953). Small spherical granules with concentric lamellae of calcium carbonate seen in the marine Oolitic limestone suggest that chemical reactions also added to the vast bulk of the calcareous ooze (Trueman, 1963). When the seas retreated for the last time, the uplift of the ocean floor raised these Cretaceous masses above sea-level. They were later inundated by molten lava extruded by the frequent and universal volcanic eruptions of the Miocene era*. This superimposed mantle of tertiary lavas protected and preserved the underlying limestone, and together they form the well-known scenic features of the present-day land mass, the rugged contours of which are mute evidence of the seething climatic cauldron from which they evolved. This magmatic caput extends over an area of 1,550 square miles, the largest single continuous fragment of basalt in the British Isles. It sometimes attains a depth of 1,000 feet (Robson, 1968).

The limestone outcrops are extensively quarried because lime and limestone play an important part in a variety of industries – agriculture, building construction, chemicals, putties, paints, ceramics and abrasives. It is used extensively in blast

* The Miocene era began 23 million years ago, and its duration was 11 million years.
and other furnaces as a flux in fusing steel. Local chalk is exported to Scotland for the manufacture of glass, for which purpose it is said to be the best limestone available. It is an important ingredient in the manufacture of cement. A low moisture content (0.53 per cent) makes Antrim limestone unique. It is consistently harder than the average English chalk, the density of which is 1.95 compared with 2.50 – 2.64 for the local rock. Whether this difference can be accounted for by a variation of the former thermal gradient in the basalt dykes, by compression of the lava load, or a combination of both is a matter for speculation. Perhaps the old geological adage applies, ‘the more rapid the cooling, the more compact the stone’, (Smith, 1868). This characteristic adds another dimension to the industrial uses of Antrim limestone. It is more resistant to the etching and corrosion caused by the acid solutions of a polluted atmosphere, than other known limestones used for ornamental building and monumental work. It retains its whiteness in the presence of such attack. This durability and resistance to chemical weathering are desirable qualities in building construction in industrialised environments.

A typical analysis of Antrim limestone is:

|             | %    |
|-------------|------|
| Lime        | 55.13 |
| Magnesia    | .25  |
| Protoxide of Iron | .06% |
| Alumina     | .04  |
| Silica      | .24  |
| Sulphuric Acid | .05% |
| Phosphoric Acid | .11% |
| Carbonic Acid | 43.59% |

|                        |     |
|------------------------|-----|
| Equal to Carbonate of Lime | 98.45% |
| Sulphur                | .02% |
| Phosphorus             | .05% |
| Iron                   | .04% |

Wherever limestone is crushed or its powder handled a heavy cloud of fine dust pervades the working arena to be inhaled by the workmen concerned. Prior to the operation flints present are culled from the bruised rock, so the residual silica content of the powdered lime is minimal, i.e. 0.24 per cent and this represents no threat to the pulmonary health of the workers, since normal lung silica is reckoned to be 0.25 per cent. (Foweather, 1939).

Free inhalation of limestone dust (calcium carbonate) observed for over 22 years revealed no clinical or radiological insult to the respiratory tract. This may seem at variance with published results. For example, Doig (1955) described eight cases of disabling pneumoconiosis in limestone workers in which limestone was said to have played the principal or sole aetiological role. However, on closer examination of that particular dust it was shown to contain 10 per cent of silicon di-oxide, and this cannot be ignored as the cause of the lung changes in these men.

The inhalation of pure limestone dust (calcium carbonate) is harmless, and does not constitute an industrial hazard.
SILICA

The regular layers of flints seen in the limestone strata, is yet another geological manifestation of the former submarine existence of the Antrim terrain. Microscopic examination reveals the presence in them of the siliceous skeletal remains of sponges, radiolarii, echini and other primitive forms of sea-life. These rocks are solid and homogeneous in structure and are composed entirely of silicon di-oxide (98 per cent), with a thin cover of calcium carbonate (2 per cent).

A local syndicate crushed these stones to a fine aggregate to sell as poultry grit. The operatives inhaled the fine dust freely, oblivious of its pathogenicity. The disastrous results of this misadventure are recorded fully elsewhere (Scott, 1964). The bulk of the particles were less than 5 microns in diameter, a size calculated to reach and stay in the innermost recesses of the alveoli (Davies, 1949), and being freshly fractured the maximal dissolution of silicic acid was ensured, a factor which proportionately exacerbated the pathological insult to the lungs. (King and Bett, 1938). Acute pneumoconiosis resulted, and of six deaths, the longest period of survival was eight years from initially taking up this occupation. All had massive shadowing on X-ray, and all became respiratory cripples two to three years prior to demise.

It seems to be a popular text-book conception when silica alone is inhaled, unaccompanied by other injurious agents that the disease runs a chronic course, and a long period of exposure is necessary before pulmonary changes take place. From observation there is little doubt that the rate of disability is directly related to the concentration of silica in the dust inhaled, and to the length of exposure. In the most fulminant case seen among the flint-crushers, the interval between initial contact and death, was only three years. The radiological effect on the lungs is shown in Fig. 1, and the autopsy lung analysis was as follows:

|                         |                   |          |
|-------------------------|-------------------|----------|
| Total Silica percentage of dry matter | 2.46              |          |
| Free Silica             | 1.89              |          |
| Ash                     | 4.84              |          |
| Total Silica percentage of ash | 50.9              |          |
| Free Silica             | 39.1              |          |

In cases of silicosis caused by inhaling limestone dust containing 10 per cent silica, a relatively moderate concentration, 18 – 20 years elapsed before partial disability began to appear. This rate of progress is consistent with the findings in series where the concentration of silica inhaled was comparable.

The association between tuberculosis and silicosis is a controversial subject. One view is that silicosis does not ordinarily cause symptoms of pulmonary disability except in the presence of active tuberculous infection (Gardner, 1947), or in rare cases of personal idiosyncrasy, or when there has been excessive exposure to the dust. A peculiar affinity for silica by the bacillus has been postulated (Kettle, 1933), and it has been stated that 75 per cent of cases of silicosis ultimately develop tuberculosis (Christie, 1960). Such statistics are an exaggeration of the position seen to-day. In the autopsies performed in East Antrim tuberculosis had no part in the massive fibrosis encountered. It is appreciated that the dose of inhaled siliceous material was excessive, nevertheless, the periods of
survival ranged up to eight years. This seems ample time for the establishment of 'symbiosis' between the element and the bacillus, if such exists, particularly as the ciliary defences and bronchial peristalsis were seriously impaired, and incessant coughing blunted the therapeutic sheet-anchor of pulmonary rest. It seems rational to deduce that silico-tuberculosis was most common when the infection rate was high in the community. The improvement in social conditions and therapeutic control have led to a marked decline in tuberculous infections. In consequence the opportunity for association between the two diseases is greatly curtailed, so the percentage incidence of silico-tuberculosis is much less than formerly. It is also of interest to note that in more recent years where the dose of inhaled silica was not gross, i.e. 10 per cent (Doig, 1955) the onset of pulmonary disability was delayed for 20 years or more, and when fibrosis appeared, it was without the assistance of complicating tuberculous infection.

The size of the inhaled particles has also received considerable attention. It has been suggested that when silica is inhaled in a very fine state of subdivision (20 Angstrom units) it is readily soluble in the pulmonary fluids, and is then eliminated

**FIG. 1.**
*Massive and terminal pulmonary fibrosis seen in a 'flint-crusher' after only three years exposure to the dust.*
from the tissues too promptly to do lasting harm (King and Bett, 1938). This point has little application in industry, since industrial machines do not discriminate as regards the particle size, nevertheless this statement is also open to doubt. In Shaver-Riddell disease, a pneumoconiosis specifically associated with the aluminium industry (Wyatt and Riddell, 1949), furnace operators inhaled fumes composed of silica (20-44 per cent), and aluminium (41-62 per cent). These percentages were reflected in the autopsied lungs as follows:

|        | Silica  | Alumina |
|--------|---------|---------|
| Dry Weight | 6.24%   | 22.75%  |
| In Ash   | 26.8%   | 38.8%   |

(Shaver C. G. and Riddell A. R. 1947)

Probably influenced by the recorded ‘innocence’ of finely subdivided silica (King and Bett, 1938) it was concluded that the lethal lung changes were due to the finely divided amorphous alumina. Practical evidence available indicates that alumina is a relatively innocuous inhalant. It has been used extensively as an aerosol of aluminium hydroxide in the treatment of silicosis (Crombie et al., 1944). Carefully controlled trials failed to reveal any therapeutic value of such a regime (Christie, 1960), nevertheless it was significant that no adverse effects were noted on the pulmonary tissues from its use. Again the substitution of alumina for flint to bed china in the pottery industry was wholly beneficial and it reduced the incidence of pneumoconiosis (Bodley Scott, 1961). Experience in East Antrim, and in the aluminium industry in general supports the view that alumina dust is not a pulmonary irritant. If this be accepted the disastrous results caused by the inhalation of bauxite fumes in Shaver Riddell disease must have been due to the silica content, in spite of the fact that it was in the very finest state of subdivision.

Radiological films are recognised to be indispensable in the diagnosis of the pneumoconioses, but alone they are not a reliable index of the degree of incapacity. Heavy shadowing can occur with minimal disability and vice-versa (Kerley and Twiney, 1950). Careful clinical examination is the prerequisite for functional assessment. Fluoroscopic investigation is helpful, as fixation of the mediastinum and limitation of diaphragmatic movement precedes such symptoms and signs as dyspnoea and diminished chest expansion, that precede reduced vital capacity. The accentuation or reduplication of the second pulmonary sound is a late sign, the cri de coeur that heralds the advent of terminal cor pulmonale.

It is a recognised fact that a workman may cease to operate in a siliceous atmosphere, when a chest x-ray is still free from radiological evidence of nodular fibrosis. Pulmonary changes may appear after an interval to demonstrate that the patient had been in previous contact with a quartz laden atmosphere. If the dose of silica inhaled is not critical, the tissue reaction may eventually subside, and the partial disability attained at that point may remain static (Gardner, 1947). One workman, for example, was heavily exposed to flint dust for a brief period of two years, and a chest film showed minimal mottling in the right mid-zone, so advice to change the occupation was complied with. Six years later this patient complained of cough and dyspnoea, with a significant reduction in vital capacity. Radiograph now revealed extensive bilateral pulmonary fibrosis indicative of the previous
contact with quartz. This picture (7/9/62) is similar to that taken more recently, Fig. 2 (28/12/72) which shows that the radiological pattern has not altered materially in the ten-year interval, nor has there been further deterioration in the clinical state. The dose of silica inhaled was probably insufficient to perpetuate pathological activity. Whatever the clinical or radiological evidence when the patient is first seen it is never too late to advise his removal from the influence of a suspected dust.

Quartz and silica are the most soluble, and therefore the most pathogenic of the mineral dusts (King, 1947), dissolving to the extent of about 10 mgm of silica per 100 cm. of blood plasma. In spite of the fact that more progress has been made in fighting pneumoconiosis since 1954, than in the previous 200 years (Posner, 1972), one hundred new cases of silicosis are reported in the potteries alone each year. The industry's failure to set up a medical service with research facilities has been criticised, as has the failure to apply properly techniques designed to cut the incidence of the disease. The frailty of the 'human element' is forever destined to be a weak link in the preventive chain.

Silicon di-oxide is a most lethal dust when inhaled. The rate of pulmonary deterioration is determined by the duration, and the severity of the exposure.

### SALT

Rock salt or halite (NaCl) is an evaporite deposit precipitated by evaporation of salt water in an arid climate from lakes or lagoons having restricted access to the sea, but with a constant trickle supply of salt-laden water moving in to replace that evaporated. (Robson, 1968). This process took place in the *Triassic era, when centuries of tropical sun relentlessly baked the East Antrim landscape. The nearest approach to such climatic conditions to-day is found only in the Persian Gulf, and parts of China, India, Japan and in the alkali flats of Utah (Carson, 1953). To preserve these crystalline deposits it was necessary for nature to cover them with an impervious material, such as clay or marl, achieved by land-slip or perhaps interred by volcanic activity.

Salt has been exported to all parts of the world for more than a century. The Marquis of Downshire struck salt at Duncrue, Carrickfergus, in the middle of the 19th century, and extracted 20,000 tons of high purity salt yearly. From 1896-1922, 600,000 tons were exported from Tennant's mine at Eden Carrickfergus. These deposits seem likely to extend over a wide area, as recent borings at Larne revealed there that beds of halite reach 1,500 feet in depth, exceeding in thickness the largest known deposits in these islands. The statistical significance of this is reflected in the deduction that a vertical foot over a square mile yields 2,000,000 tons of salt. It is difficult to understand why such resources are allowed to lie fallow. It seems reasonable to hope that a commercial option will be exercised in the not too distant future.

Latterly the salt was obtained by flooding the holdings and piping the resultant brine to the purification plant and the evaporation pans. This process does not

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*Triassic Period: began 220 million years ago, and lasted 40,000,000 years.*
FIG. 2. Extensive pulmonary fibrosis which developed after a latent period following exposure to flint dust.

FIG. 3. Changes of pulmonary fibrosis seen after 30 years exposure to bauxite dust.
appear to have been associated with any particular health hazard. It is noted in the Factories Act N.I. 1938-1949, under the heading of Prohibited Employment that “Female young persons must not be employed in any part of a factory in which are carried on evaporation of brine in open pans or stoving of salt.”

The mining and processing of salt, apart from minor discomforts, does not present an industrial health hazard to the operatives concerned.

**Bauxite**

Bauxite is the parent ore from which the metal aluminium is derived. It is so-called because it was first discovered at Les Baux, a town in Southern France. A country-wide survey of the British Isles revealed that bauxite deposits are absent except for an area in County Antrim (Edmunds, 1960). Here highly aluminous clays are found to exist between the old lava flows in the Interbasaltic interval. During the last year over 300,000 tons of bauxite were extracted from mines in the hinterland under the managing direction of the British Aluminium Company, and initially processed at their works in Larne. Ample reserves of this ore still remain.

Silica (SiO₂) is the commonest magmatic element, and the key substance in the crystallisation of rocks, comprising 65 per cent of the Earth’s bulk. Another 15 per cent is composed of alumina (Al₂O₃), a combined total for both of 80 per cent (Drury, 1964). In nature these elements form a tenacious affinity for each other, the stability of which is extremely difficult to disrupt. Their separation is naturally accomplished, however, by a process known to the geologists as ‘weathering’. The principal agents of which are the atmosphere, water, and the sun’s energy. The primary lithomarge is exposed to incessant physical, chemical and organic assault in tropical monsoon conditions. As one would expect temperature plays a key role. The difference between night and day temperatures in some tropical areas to-day often exceeds 100°F (Raistrick, 1963). In consequence non-related minerals contained in a rock, by virtue of their different co-efficients of expansion, expand and contract unequally when subjected to the same rise and fall in temperature. Such constantly repetitive internal stresses eventually reduce the crystalline crust to a granular state. Rain has a devastating weathering effect. It is a complex fluid. As it falls through the atmosphere it dissolves small quantities of various gases. On reaching the ground it is a very dilute solution of carbonic acid, and in industrial areas sulphuric acid, and the contained oxygen acts as an oxidising agent. This acidulated solution attacks rocks destructively down their joint planes, and chemically alters existing minerals in the rocks, which in turn may interact with neighbouring substances to form different compounds. Through time rain alters the previous integrity of a rock, so that it may eventually be replaced by a virtually new mineral. (Desaults, 1969). Showers also carry swarms of micro-organisms, Chadothrix, etc., from the surfaces into the crannies of the rock where all catalyst reactions are intensified by the warm climate. When it freezes, water expands by one tenth of its volume, exerting a pressure of 200 lbs. per sq. inch. Decomposing vegetable matter on the ground produces humic acids and these percolate to set up their own individual chemical changes. The winds
carry fine sand and rock particles, to exert a powerful kinetic action capable of eroding the hardest of surfaces.

Chemical weathering breaks the rock down into soluble and insoluble compounds. The bulk of the former is forced into solution, which includes silica, lime, magnesia and alkali of the original rock. These leach out to leave insoluble substances behind to form the new rock, composed of aluminium, iron, titanium and sometimes manganese. This process of desilification is known as 'laterisation'. Should it happen that the insoluble hydrates of iron remain the dominant content of the 'new rock', and of sufficient quantity and purity to make commercial recovery worthwhile, it is termed iron ore or laterite. If on the other hand the residuum is composed mainly of aluminium hydroxide, it is an aluminium ore and is called bauxite. This weathering process is maximal in areas of low latitude, e.g. in tropical Ghana, the Carribean, Southern France, etc., where abundant rainfalls co-exist with warm atmospheres to accelerate the speed of chemical oxidising reactions.

The climatic conditions necessary for the development of laterites and materials rich in alumina are so specific that the occasional presence of these substances in stratified rocks, e.g. in the Interbasaltic Horizon in County Antrim, is regarded as factual evidence of the former existence of tropical weather during the time of their formation. (Kirkaldy, 1962). This was during the *Eocene and *Oligocene eras, when the atmosphere was hot but not arid (Cole, 1912), e.g. warm suns and heavy rains, conditions that prevail to-day in many parts of India and Africa. Proof that such a climate existed in East Antrim is preserved in the volcanic lavas of the Miocene eruptions which enveloped the terrain. Traces of tropical vegetation can be identified in the magma, such as eucalyptus, sequoia and grasses that are found growing to-day in Southern Europe and North Africa. (Charlesworth, 1966).

Weathering is a slow and imperceptible process, and its existence may be doubted by many. It has to be remembered, however, that geological time is measured, not in tens, but in millions of years or more. During these vast periods of time, the agents of denudation have been ceaselessly at work, and the weathering processes of the milennia are continuing at this moment in time. The bauxite beds of the Antrim Lava Plateaux are 20 feet deep, and are said to represent a developmental period of one million years, whilst in Ghana, from whence high grade ore is imported, the 60 foot beds there are computed to have taken 7,000,000 years to form (Cooper, 1936).

Bauxite is chemically an impure form of aluminium oxide (Al₂O₃). It is combined with water, silica, iron oxides and titanium, the residual impurities left with the rock after weathering, and which must be eliminated before the pure metal is extracted. The formula for high grade bauxite is:

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* The Eocene era began 70 million years ago, and continued for 35 million years, whilst the Oligocene era started 34 million years ago, and its duration was 12 million years.
Al₂O₃ (Alumina) 50–70%
Fe₂O₃ (Ferric oxide) 3–25%
SiO₂ (Silica) 1–7%
TiO₂ (Titania) 2–3%
H₂O (Combined Water) 12–40%

(Aluminium Federation).

The ore taken from one of the local mines was exceptional so far as Irish rocks are concerned, in that it had a very low silica content – 1.6 per cent, with a high compensating percentage of alumina – 62.7 per cent. Other sources were not so rich, as silica figures range from 1.6–8 per cent in the holdings worked. The raw material was transported to Larne, and there crushed to a fine powder in the rolling-mills. This was then digested in a hot solution of caustic soda, which dissolved the aluminium oxide. The undissolved impurities, i.e. coarse particles of the oxides of iron, titanium and residual silica were creamed off leaving a clear liquor, which in turn was calcined in rotating kilns at 1,300°F, and a white powder, anhydrous alumina (Al₂O₃) was deposited. This is the intermediate product in the manufacture of aluminium metal. As further reduction depends on ample supplies of cheap electricity which can only be supplied by vast hydro-electric schemes, the alumina was of necessity transported to the Scottish Highlands where these exist. It may, therefore, be of interest to recall that technological methods available in the early part of the last century produced infinitesimal amounts of aluminium. Isolation of the metal on a commercial scale resisted scientific endeavour until 1866, when by a strange coincidence Charles Martin Hall of the U.S.A. and Paul Herault of France, independently discovered the Hall-Heroult electrolytic reduction process, whereby powerful electric currents tore asunder those elements that had been tightly interlocked for billions of years. The alumina is dissolved in a bath of molten flux to allow the hefty current pass. This liberates the oxygen and releases the molten metal to a purity of 99–99.8%, and it is then readily decanted. As a consequence of this discovery cheap electricity became a paramount industrial necessity for the economic production of aluminium. The British Aluminium Company (1894) pioneered the development of powerful hydro-electric schemes in the Highlands of Scotland where ample supplies of surplus water exists. The Fort William project is but one example of engineering ingenuity and skill required to overcome formidable natural obstacles to provide adequate power. Water from a three-hundred square mile area is collected into a complicated catchment system of dams, and conduited by a 15 foot pressure tunnel, for 15 miles through metamorphic rock, schist and granite, through and under the heart of the Ben Nevis mountain range to deliver 6 – 7,000,000 gallons of water a day to the reduction plant. The reafforestation of catchment areas, and the development and stock of the new pasture lands, with the construction of adequate housing established a balanced environment to achieve an advantageous symbiosis between agrarian and industrial interests all too uncommon where technological development superimposes itself on a rural terrain. The substantial amounts of electricity necessary is reflected in the production statistics of Alusuisse (1888), Zurich, the European pioneers of aluminium production. In 1969 this Company produced a

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record output of 1½ million tons of the metal which required 7,500 million kilowatt hours of electricity (15 kilowatt hours per kilogram). This is enough to satisfy the electric power needs of a city of 2,000,000 inhabitants for a full year. It will thus be obvious why it was necessary to transfer the alumina from Larne to the Scottish reduction factories.

The ability of 'aluminium' to cause specific lung disease is debatable. The term 'aluminium dust' appears frequently in the literature, but this term requires careful definition. Such a dust may vary in chemical composition and possible pathogenicity according to the stage reached in processing when the 'dust' presents.

The crushing of bauxite ore is the first step in the eventual production of aluminium metal. The rock is reduced to a very fine powder which heavily pervades the factory atmosphere. It was freely inhaled and preventive measures were not deemed to be necessary. Many were exposed for periods of 30 years or more, and no clinical disability was attributed to the nature of the work. The men exposed volunteered the information that when the rock was being crushed workmates were scarcely visible nearby owing to the density of the bauxite powder in the atmosphere. Examination of all available chest x-rays showed a moderate degree of abnormal shadowing in them all, some more pronounced than others. In Fig. 3 the pulmonary changes developed after 28 years exposure, and at the time the picture was taken the patient had been retired for 28 years, aged 82, was physically well without respiratory embarrassment. Enquiry at the large reduction works revealed that there was little or no incidence of pulmonary disease among bauxite crushers. It may be that the Antrim ore was marginally higher in silica content (1.9 – 8 per cent) than high grade imported ore, and this may be sufficient to cause mild tissue reaction but insufficient to give rise to functional pulmonary change. The record of longevity in the local workmen is testimony to the relative innocence of the inhalation of bauxite dust. At the most it produces a benign pneumoconiosis with the suspected help of a moderate amount of silica.

The second stage in the production of the metal is the digestion of the powdered bauxite with caustic soda, and the resulting liquor is calcined by strong heat to produce a fine white dust or alumina (Al₂O₃). Inhalation of this dust did not produce any adverse effects on the pulmonary system when inhaled over the same periods of time as the fellow workmen above.

It is concluded:
(a) The inhalation of Antrim bauxite dust causes a benign asymptomatic pneumoconiosis.
(b) This inhalation of alumina (Al₂O₃) is innocuous.

It is perhaps appropriate to refer again to Shaver-Riddell disease to clarify its relationship to the aluminium industry. Alumina (Al₂O₃) is a corundum, and other forms of this material occur in nature such as sapphire, oriental ruby, topaz and emerald. It has a basic hardness next to diamond, i.e. 9 on the Moh's scale of hardness. This characteristic has been utilised by industry to produce a commercial abrasive. To do this bauxite was mixed with coke and iron and the mix fused by an electric arc at 2,000°C. The dense fumes evolved were inhaled by the furnace-men who contracted acute pneumoconiosis in consequence. It was postulated that the lung changes were due to the alumina content of the fumes.
This seems unlikely in view of experience in East Antrim, and in the aluminium industry in general. It is likely that the pathological injury in the lungs was caused by the high concentration of finely divided silica inhaled, and that Shaver-Riddell disease was in fact acute silicosis, and not an aluminium lung disease as is commonly supposed.

Cement

Portland cement is 90 per cent alumina, lime and silica, with ratios of \( \text{SiO}_2 / \text{Al}_2\text{O}_3 \) varying from 2 : 1 to 5.5 : 1 (Lea, 1956). The basic raw materials for the manufacture of cements, exist in close proximity on the Antrim coast (Magheramorne). The requisite lime or calcium carbonate is readily quarried from the outcrops, and the siliceous alluvial mud or clay is conveniently obtained by dredging from the bed of the adjacent sea-lough.

Clays are formed from decomposed weathered detritus of argillaceous rocks, felspars and other materials. Mixed aluminium silicate and hydrate is the basis of all clay. These hydrated alumino-silicates are in a state of very fine clastic subdivision, with a particle size of less than 0.05 mm in diameter. (Drury, 1964; Raistrick, 1963; Keikie, 1903). Their fine subdivision was assisted during the *Ice Age by the relentless too and from movement of an ice-cap, up to two miles thick, which covered most of the British Isles. When the seas grew warmer and the glacier melted and retreated, the glacial deposits of alluvial clay were left behind (Lawlor, 1928). Blue mud is the most generally found, and it owes its colour to its content of iron sulphide, arising from the decomposition of organic substances (Gunther and Deckert, 1950).

A typical analysis in per cent of lough clay is:

\[
\begin{align*}
\text{SiO}_2 & \quad 53.12 \\
\text{Al}_2\text{O}_3 & \quad 13.22 \\
\text{Fe}_2\text{O}_3 & \quad 5.05 \\
\text{CaO} & \quad 7.26 \\
\text{MgO} & \quad 2.76 \\
\text{SO}_3 & \quad 0.24 \\
\text{Sulphide} & \quad 1.04 \\
\text{Alkalis not determined} & \quad 4.48 \\
\text{Loss on Ignition} & \quad 13.22 \\
\text{Silica Ratio} & \quad 2.91 \\
\text{Alumina Ratio} & \quad 2.62 \\
\end{align*}
\]

(Lee, 1956).

The first step in the manufacture of cement is crushing the limestone, and there is an admixture with flints, so this is a possible focal point for the inhalation of a siliceous dust. This does not in fact occur, because ‘damping down’ keeps the atmosphere of the working arena perfectly clean. This aggregate is then conveyered.

* The Ice Age in Ireland began a million years ago, and the Glacial Maximum was 200,000 years ago. It is 20,000 years since the bulk of the glacier passed on, and 8,500 years ago the last remnants of the ice disappeared (Charlesworth, 1966).
to the wet grinding mills to be mixed with water and lough clay in predetermined amounts, and ground into a homogenous 'slurry'. This mix is passed through great steel rotary kilns, and ignited at a temperature of 3,000°F, and the substance 'clinkered', and then cooled. Clinker consists of complex silicates of lime and aluminium, and it is ground to a fine powder to which gypsum (hydrated sulphate of calcium) is added in specific quantities to control the setting time. This cement is then conveyed to silos for bagging or to fill bulk containers. The entire process is automated, and workmen are not exposed to dust in these terminal stages of manufacture. In addition the silica in the cement is altered to complex silicates mentioned, and these are not injurious if inhaled.

The atmosphere within the factory is surprisingly wholesome and free from dust. The 'smoke' that emanates from the chimney stack, a high level emission, is composed of steam and cement. It causes some comment as it settles in a fine dust film on surrounding property. It is not injurious to health, and the quantity is minimal because the bulk of the dust is removed in transit by an expensive and elaborate system of electrostatic precipitators. Lay opinion is naturally apprehensive of atmospheric industrial dusts, and fears are sometimes stimulated unnecessarily by un-enlightened comment. The factory provides high grade employment without health risk to its employees. Statistics from the huge cement factories abroad substantiate the claim that the health record of the cement industry is second to none. Some 2,278 workers exposed to cement dust for ten years did not develop any pulmonary disability or show radiological changes of pneumoconiosis (Gardner et al, 1939); 250 men engaged in making and 300 using cement showed no respiratory changes on prolonged exposure to the dust (Dervillee and Carrere, 1935); 533 workers in manufacturing cement showed no cases of pneumoconiosis but silicosis was seen in workers who obtained the raw materials, i.e. the quarriers and miners who worked in the marl beds (Parmegianni, 1951).

There are no health risks involved in the manufacture of cement.

The elements described above are but a small proportion of the hundred or more that exist in the Earth's crust. Tempered by the heats, the cataclysms and pressure of climatic extremes they provide the opportunities for the technological scientists to make discoveries beneficial to mankind. The genesis of knowledge, however, down the centuries has been subject to inexplicable 'crescendos and dimuendos' and even phases when the fruits of scientific achievement have been apparently lost. It is fitting that aluminium, the 'youngest' metal in existence to-day should pose this intriguing possibility. According to modern records the first particles of the metal aluminium were produced by a Danish chemist, Hans Christian Ørsted in 1825 using a chemical process. Yet it is noted that an ancient girdle found in a third century tomb of a Chinese General Chow Chu (A.D. 265-316) was found to contain on spectrascopic analysis, 10% copper, 5% manganese, and 85% aluminium. There may be occasions when a scientific discovery may in actual fact be a 're-discovery'. The most recent and important scientific advancement, the atomic pile, which produces power, radio-active isotopes so useful in treatment and diagnosis, is completely dependent upon raw materials extracted from the Earth's crust. It can be reasonably argued that the Science of Geology is the handmaiden of technological achievement.
In a journey around East Antrim the trained eye can readily discern the tell-tale signs of the climatic conditions that prevailed in the periods described in the text above, e.g. evidence of the relentless desert heat in the Triassic period, the more pleasant subtropical climes of the Eocene and Oligocene periods, and the snows and blizzards of the Ice Age. Geology is the ‘braille’ that will open the eyes of the uninitiated into a wider understanding of the topography of the land in which they dwell, and the significance of those features which point to the mineral wealth which may lie below a surface. Furthermore, the enthusiastic amateur geologist has it in his power to make discoveries that have not yet been recorded. It seems that this subject should receive more serious consideration in the curriculum of secondary education.

SUMMARY

The commonest magmatic element, silica, has been one of the most potent causes of pneumoconiosis. The severity of the pulmonary reaction due to quartz dusts depends on the concentration of silica in the inspired air, the length of exposure, and the freshness of the fractured particles. The pharmacological composition of the dust is also important, e.g. heat-treated silicon di-oxide is particularly dangerous, because the modified forms of silica so produced are biologically more active than the parent substance. Wherever a siliceous dust pervades a working arena, stringent precautionary measures are mandatory at all times.

Halite or salt (NaCl) presents no threat to industrial health. The Factories Act N.I. (1938, 1949) does, however, prohibit “female young persons” to be employed in that part of a factory where the brine is evaporated or the salt stoved. In the absence of information for the necessity of such a stricture, it is assumed that there may be local irritant causes, but there is no respiratory hazard in the processing of salt.

Bauxite dust is not regarded in the aluminium industry as a noxious respiratory agent. The relatively benign pneumoconiosis seen in the bauxite workers in East Antrim are likely to have been due to the moderate silica content of the ore, the dust of which when crushed was freely inhaled by the operatives concerned.

Limestone dust (calcium carbonate) can be inhaled in unlimited quantities without damage to the pulmonary tissues. It is necessary, however, to carefully cull the indigenous ‘flints’ prior to crushing the rock.

Cement dust can be inhaled with impunity. The high level emission of this substance from the factory chimney is a moderate physical nuisance to people and property within its atmospheric range. This has been latterly markedly reduced by sophisticated electrostatic precipitation procedures.

Alumina (Al₂O₃ – corundum), a fine white powder and an intermediate product in the manufacture of the metal aluminium, has no deleterious effects on the pulmonary system when inhaled. Alusuisse, the Swiss pioneers of aluminium production in Europe, founded 1888, and one of the world’s principal producers of the metal, “have never heard of any case of health hazard due to alumina.” (Swiss Aluminium Ltd. 1973).

Atmospheric concentrations of fumes and dusts can now be monitored and accurately measured. Threshold Limit Values (T.L.V.) have been evolved for individual inhalants. These indicate the levels of atmospheric contamination to
which a workman can expose himself day after day without adverse effects. It has not been found necessary to assign Threshold Limit Values to cement, limestone dust, or alumina. These substances are merely classified as "Inert" or "Nuisance Particulates". (D.E.P. 1971).

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