Geoscience education: the foundation of truly sustainable development and a high quality of life for all people

W. S. Fyfe

University of Western Ontario, Dept. of Earth Sciences, London, Ontario, Canada N6A 5B7

Abstract

We must understand the history of our environment. For example, what would happen today if we had a volcanic event like Krakatoa, 1883? This has been described in a recent book by Winchester [13]. Given a “year without summer” how many people would die? One thing is certain: we must have a surplus of life support components.

Our life support and health are related to many key components: We must have clean air to breathe and we would not be here without the green plants. We must have clean water to drink. We must have quality food and surplus food security depends on climate, water and soil quality. We must have biodiversity for security when climate fluctuations occur. Given our present population, we must develop adequate clean energy. This is possible, if we use the sun and the warm rocks under our feet, all natural nuclear energy. We must have an adequate supply of materials and we must develop new technologies as with mining. For many purposes we must have new construction and transport technologies which do not waste the planet’s surface resources. There is huge potential for underground construction and the use of marine resources. We need new technologies to reduce waste and for recycling waste. Here Europe leads!

World data are clear. Where there is a high quality of education for all people of all ages, male and female, population is decreasing and quality of life is excellent. In the development of needed new technologies, we require new teams from all the sciences, engineering, politics, and we need new economics which consider the needs of future generations. We live in the age of TV culture, but who controls the quality of TV information?
1 Introduction

We are living in a period with vast problems, environmental, social and economic. There have been many of these problems before but what has changed is the scale related to the huge increase in human population. After the birth of Jesus Christ it took 1700 years to double the human population. Then came modern science, technologies, etc. The world population has doubled twice in my lifetime and in many parts of the world the population has doubled in the last 50 years. At the present time, thousands of people, mostly children, die everyday from disease, malnutrition and pollution of many types (air, water, soil). In 1993, Daniel Koshland, the former editor of the journal Science, discussing such problems wrote: “First of all it is important to identify the main villain as over population”. As I will discuss later, he was wrong. The main villain in our world is lack of quality education, particularly for females.

What are the main global factors that determine our quality of life and the outlook for future generations? I always think that a great question is as to why it took so long for us to arrive on planet Earth. Recently Skinner and Berger [11] edited a classic volume “Geology and Health, Closing the Gap”. In this they review major geo-factors influencing health and below I discuss most of these factors.

2 Air quality

Given the huge developments of urban regions, in many nations over 90% of the population, and given chemical and transport technologies, in many nations the air quality is a major cause of a variety of health problems. Often a major component of air and water pollution is the burning of fossil fuels, coal, which contribute greenhouse gases like CO₂, acid rain and a variety of other components such as lead and even arsenic. Another component attracting more attention is dust, the general factors are discussed by various authors in Skinner and Berger [11] and Fyfe [6]. Recently, November 12, 2003, the Manchester Guardian Weekly described atmospheric pollution coming from the U.S.A. which produces 25% of the world’s carbon dioxide emissions. If all people on this planet used the same technologies as in North America, we would have a global disaster! Fortunately, many nations, particularly in Europe, are reducing such pollution. The technologies are available now!

3 Water quality

During my field trips (geology and environmental science). I have walked in over 62 nations, in urban areas and farm country. A question I always ask the local people is if the local water is safe to drink without treatment. In the majority of nations the answer is no and today we have the vast industry related to bottled water. The subject is well reviewed by Postal [10] and Skinner and Berger [11]. In addition, all over the world more and more water is held by vast construction of dams. This can cause more pollution by dust, fertilizers, and a
host of industrial chemicals. Again, many examples are given in Skinner and Berger [11].

It is interesting that in some nations the situation is improving. I was very impressed by a recent visit to the coastal regions in Western Japan. In the hill country, in some valleys, no farming, no people living, the valleys were natural water storage regions. In many regions, recent climate change with decreasing rainfall, has caused major disasters for all life forms (e.g. the Sahel of West Africa as described by Zeng [14]).

4 Nutrition

In many nations on this planet, adequate quality food is not available. Malnutrition is a major cause of death. There are many nations in Africa where life expectancy is below 50 years and the major causes of this include water and food quality and quantity. Food production and food quality are related to climate, water, biodiversity and soil physics and chemistry. Today, many major global projects involve water and biological factors but soil science is often neglected.

In many parts of the humid tropics as with the Amazon region, the soils are deficient in a host of key nutrients for plant growth and our health (e.g. the laterite soils of the Amazon, see Fyfe [4]). In the past two decades we have been involved in improving some of the soils in India using certain waste products like coal ash and mineral and rocks. The results have often been spectacular and with little pollution (see van Stratten [12]). And here I am always reminded of the words of the great philosopher Montaigne, 1580, “the most universal quality is diversity”. But if you work on a farm you also know that diversity of plants and animals is security. The one crop farm cannot survive climate change.

Finally, there is great need for surplus food. There can be many types of accidents on this planet. A spectacular example was the Krakatoa volcanic eruption in Indonesia in 1883. This eruption poured vast quantities of dust into the atmosphere and changed the world climate for over a year (see Winchester [13]). Europe had a year without summer. If we had an eruption like Krakatoa tomorrow, how many billions would die of starvation?

5 Clean energy

Our quality of life is influenced by the availability of low cost, sustainable energy. We need energy for a host of our life support components. If we compare per capita energy use (in Giga-joules) World 59, USA 317, Japan 141, Germany 170, Brazil 24, India 10, Africa 13, it is clear that most regions need more energy while some nations waste energy, and waste valuable resources, resources which more often than not come from outside the countries themselves.

Currently, most energy comes from the combustion of liquid, solid and gaseous carbon fuels, and today there is vast concern with the fact that we have changed the chemistry of the atmosphere and the climate. Emission of CO₂ per
capita, in metric tons is per capita, USA 20.5, China 2.7, India 1.0. What would happen if all people on Earth behaved like the USA? Would we have a greenhouse or Venus? Many new studies also show that hydropower is not benign.

Our energy technologies are not sustainable. Many estimates of our fossil fuel resources show that at present rates of use oil will not be the major fuel by the end of this century. Reserves of coal are much larger. But increasingly there is growing interest in natural gas and particularly methane, and the use of new types of fuel cells which produce electricity from the oxidation of methane. Also vast quantities of methane have been discovered in various parts of the sea floor. There is also great interest in using deep bacteria to react with carbon bearing rocks to produce methane: coal mine methane could be a fuel for the future. The question of whether we still use fossil carbon sources and reduce greenhouse gas emissions (CO₂ and CH₄) is attracting great attention worldwide. There is great interest in the possible disposal of CO₂ from stationary power plants, in the oceans or underground. Many have stressed that this would add substantial costs and use energy. But as much work shows, when CO₂ is added to certain rock types which generate carbonate minerals, the reactions are highly exothermic with as much as an extra 40% energy production. The bonus to disposal would be warm water.

Recently a new problem has been exposed which relates to the points made about dams and water control to the problem of CO₂ generation. Across the world more and more large dams are being built to store water for agriculture and hydro-electricity production. But recently it has been shown recently that when many new dams are put into use, rotting vegetation produces methane for decades. Methane is a more powerful greenhouse gas than CO₂. As Pearce [8] shows, that for the same power production, a dam with organics, can produce more greenhouse gas than an energy-equivalent coal-fired plant over the first 20 years of its existence. Furthermore poor irrigation systems, too much evaporation, can lead to salinization of soils and reduced biomass production and carbon fixation.

Does nuclear energy have a future? As discussed above, fossil carbon fuels cannot provide for human needs using current technologies. There is no doubt that fifty years ago, scientists saw vast potential for nuclear power. It became a major component of electricity production in many parts of the world; Ontario is a prime example. Many still believe that new development in fusion technology have a future and suggest a nuclear solution to climate change. Yet, two problems have become recognized. First as recent events in many nations have shown (Chernobyl is the standard example) there must be no accidents! Second, a vast and very expensive problem is that the wastes from reactors must be isolated from the biomass for millions of years. And this raises the great geo-question. Where are the best places for secure isolation? An additional hazard arises from the fact that, as the mass of waste increases, the possibility of its use in weapons increases. In a recent paper, Pease and Roberts [9] show that at present, on Earth’s surface, there are enough waste materials to make over
200,000 Hiroshima scale bombs! Nuclear waste isolation is truly an urgent international responsibility (Fyfe [5]).

So, considering all these problems, is there a reasonable solution? We are not short of alternatives. If we could collect and use solar energy for half a day per year it would provide all the energy needed for 10 billion humans. Solar comes in many forms and their uses are expanding worldwide. Recent reports from the Worldwatch Institute show the rapid changes. In the period 1980 to -1998 wind power generation increased from 10 megawatts to almost 10,000 megawatts. In Germany, in particular, there is a huge expansion in the use of wind energy. As with all solar energy systems they can be used on all scales. Photovoltaic devices are also increasing in use (0.1 megawatts, 1971 to about 200 megawatts, 2000). And here it is important to note that the cost of solar cells is reducing rapidly from about $100 per watt in 1971 to less than $4 today. Japan is today one of the leading nations in this area.

There is greatly increased interest in using patterns of waves and ocean currents for power production. In England there are important new developments in technologies to produce energy from ocean currents. We are learning much about changes in the ocean currents, intensity and patterns. It has been said that in the U.K. tidal energy could produce 20% of the electricity by 2020. And we must not forget that, given the correct geography, there is no need to heat water except by the sun! The use of solar collectors is growing in all intelligent nations and here I am always impressed by certain types of ancient architecture, in hot and cold regions, designed for comfort long before the advent of electricity.

Another important new development involves the use of photo-dissociation of water. This technology is based on the fact that when the sun shines on certain metal oxide surfaces, like Cu$_2$O, water is broken into 2H$_2$ and O$_2$ – almost the perfect fuel for transport devices. But there are problems. As Ananthasamy [1] discusses, hydrogen pollution of the atmosphere could be very destructive.

Historically, biomass fuels, plants, wood, etc., dominated many solar energy devices. There is no doubt that in certain nations which have space and the ideal climates and soils, bio-fuels must have a positive future. It is of interest that the great Shell energy company is promoting biofuels for the future. As indicated in a recent Shell advertisement “the future is taking root”. Their new group “Shell International Renewables” is working in many parts of the world to produce biomass fuelled electric plants. They state that “in 2050, half the world could be powered by renewable energy”.

Biomass energy has great potential, but to make such systems truly sustainable soil erosion must be near zero. And the soil chemistry must be conserved. If a particular plant species requires certain chemical elements for high productivity, these must be maintained in the soil. Depending on the fuel process, with simple burning, all waste must be returned and appropriate minerals, chemicals, be added to maintain the chemistry. Historically, this has been rarely done.

There is another new aspect of biomass energy which required attention. Work in New Zealand has shown that certain trees accumulate metals like gold.
Thus where there is an anomaly as with old mine tailings, hydrothermal muds, trees may accumulate gold up to 57 ppm dry weight; a very high grade ore. An experiment that could be developed is to grow trees in an anomalous zone, use the wood for fuel and extract the ash for metals. Many bio-species can collect metals, provide fuel, clean water and produce a valuable product.

Biomass energy has great potential but to develop this potential requires integration of knowledge from many sciences, bio, geo, agri, and climate…! We must produce the needed teams. And every day there are new developments. As reported in the journal, Chemistry in Britain (April, 2000, p. 19) it is now known that certain species of “algae strike it rich” as by biophotolysis they produce hydrogen and oxygen from water!

The general aspects of geothermal energy have been widely discussed. In general, temperature increases with depth in the Earth’s crust at a rate of 20-30°C per kilometer. In volcanic regions, large masses of hot rock (1000°C) are present near the surface. A few countries, for example, New Zealand and Iceland, have made major use of this energy source at competitive prices. There are problems when very hot water is extracted, for it can be rich in components like hydrogen-sulfide, arsenic, and heavy metals. These products can be largely eliminated by recycling the hot water to depth, avoiding direct discharge to rivers.

The energy in hot rocks, ultimately derived from the radioactive decay of isotopes of elements like uranium, potassium, and thorium deep in the Earth, is impressive. One cubic kilometer of rock of mass $3 \times 10^{15}$ at 1000°C will provide about $4 \times 10^{18}$ joules of energy as it cools to surface temperatures. Thus, 100 km$^3$ of hot rock could supply world need for a year. Current production of 1200°C magmas is about 15 km$^3$ per year, but the volume of associated hot rock is much larger. There are many well-known regions of the world (New Zealand, Japan, Philippines, Chile, Iceland, California and East Africa) where such situations are common. Most sites occur near the great plate boundaries or rift systems of Earth.

There are also some regions which have not been adequately explored. Many parts of the ocean floors show unexpected high temperatures. In part this may result from cooling the ridge basaltic intrusions which drive plate motions and in part by exothermic serpenitization of deep mafic rocks. A very interesting case is provided by the Juan de Fuca ridge off the west coast of Canada. The new hot basalts are rapidly covered by clay sediments. Geophysics and drilling has shown temperature gradients up to 400°C km$^{-1}$ through the clay cover. Beneath the sediments are vast volumes of hot water! But the water is saline and this opens up vast new opportunities. First the deep water in the porous basalts could be used for energy production, and second, the hot salt fluids carry metals like manganese, iron, zinc, copper, silver and gold. Could we develop a technology, at sea, to extract the metals and energy together?
6 Materials

Next, consider our material resources. Most of our material resources come from the outer 5 km of the continental crust of our planet. People in advanced countries use about 20 tonnes of rock derived materials, per person, per year, for their needs. For the population of the future this means that the mass of rock processed by human actions will exceed that by all natural processes such as volcanism. We must change this careless pattern of management: there is a huge need for quality control, and a detailed chemical knowledge of what we take from the Earth. A classic example is provided by coal. Fossil carbon mined for energy can include a host of other elements. Work in our laboratories has found coals mined on a massive scale containing significant concentrations of elements like arsenic and of great interest, all halogens (fluorine, chlorine, and bromine) which are discharged from combustion as halogen acids. Does this affect the ozone hole? Classic work has been done by Finkelman and associates [2] on coal burning and public health in China. Problems include serious fluorine, arsenic, mercury, selenium pollution.

People like to find gold but in most processes that form gold deposits many other elements like arsenic, sulphur, lead, etc. are concentrated. In general, these waste are discharged into local soil-water systems. Recently, Herman [7] has reported on the impact of gold mining in the South Pacific region of Papua New Guinea. In this region companies from the USA, Canada, Australia, Europe have developed gold mining in many places. As stated by Herman “many of these projects have caused significant deforestation, forced migration and the release of industrial waste-cyanide, arsenic, lead, copper into nearby waterways, killing all life in several rivers”. And the sociological disturbances are alarming. Such pollution problems have occurred in many regions of mining in the developing nations. It is clear that we need a new code of international ethics.

Can we provide resources with minimal disturbance of the precious environment? The answer is positive. In the past decades there have been remarkable discoveries of metals such as iron, manganese, copper, zinc, gold, silver, platinum in the seafloor environment in many regions of the planet. We need new engineering technologies to collect such materials with minimal disturbance. Many areas of the seafloor where warm volcanic rocks are cooling have thermal waters. As I mentioned above, we can surely use these for metal and energy production. Again, we need new technologies.

Over the past decade or so, new studies of life beneath the Earth’s surface show that most porous, cracked rocks with fluid to depths of over 4 km, temperatures up to 115ºC, contain prolific and diverse microorganisms. Increasingly it is thought that this is where life first developed on our planet. A great question is “can we use these organisms to release metals from certain types of potential ore bodies?” For example, most of the great copper and zinc deposits are in sulphide minerals. By using appropriate drilling technologies plus sulphide oxidizing bacteria, plus correct fluid chemistry, can we bio-leach ores in situ and not dig vast holes? Fluids in many hot regions, sea floor and continental, show it is possible.
In large open pit mines we need to plan for the end use of the disturbance. I have seen such mines now used for aquaculture. By careful waste management, such mines could be used for biogas, methane production from urban wastes.

It is interesting that most people do not know where the things we use come from. For example, most of the iron ore used by Japanese industry comes from giant mines in the Amazon of Brazil. Recently, in one of my first year classes at Western we weighed the average gold ring worn by the ladies. The average weight was about 10 grams. The students did not realize, that on average, they were wearing the product of mining 3 tons of rock, crushing it, and extracting the gold with cyanide. They were shocked!

7 Wastes

Waste must also be considered. The increasing growth of megacities and urban populations - in industrial nations 75% of the population lives in cities, and the world average is over 45% - leads to vast global problem of waste management including technologies leading to massive air-water pollution. With all wastes, the first problem is quality control of the source of the waste. With good quality control at the source, recycling technologies become more positively economic. With such problems, Europe leads the world. There is almost a rule in Europe, that if the substance cannot be re-used, then it is not available. For example, Switzerland recycles more than 84% of glass, compared to 28% in the U.K., Spain recycles more than 78% of paper, cf the USA, 34%. If you shop in Germany, take your own bags and baskets just as our grandmothers did 100 years ago. Waste is bad economics and bad for the environment.

Recently I have been involved with the potential use and reduction of waste problems. On my parent’s remote farm in New Zealand we had no wastes. All animal manures (including human) were used to improve soil and in those days of the 1920’s, there was little paper and zero junk mail. There were no plastic bags! I was recently at an environmental meeting in Hamburg, Germany. We met with the city engineers. Their rule is that if it can’t be recycled or re-used, you can’t have it! Organics, etc. all go to farm lands. Much of the organic wastes, paper, etc is used for fuel for electricity production, heating. Unlike Toronto they no longer require land fills. Why can’t we learn from Europe! In India and China, which produce most of their electricity from coal burning, often high ash coal, I became interested in the disposal of coal burning wastes. In many places this material had caused massive destruction and economic loss, by such practices as dumping in rivers.

When any waste is used, step one is to understand the total chemistry. In Indian coal ash we found interesting quantities of plant nutrients like potassium, calcium and phosphorous. In many cases there were no serious toxic elements. For coal this is not always the case. One of my colleagues, Dr. Brian Hart has found high concentrations of elements like arsenic in coal, being used in Thailand for power production. Similarly I found arsenic in coals being used for cooking on the street in Beijing. Much of the ash in India was free from such elements. Since many of the soils in India are depleted in nutrients, as in many others...
warm, wet regions of the globe, such ashes prove a useful source of soil nutrients. When we added coal ash, and at times urban wastes, to the soils, bioproductivity increased by factors of two to ten times! The waste was valuable for agriculture given quality control. In Brazil where poor, leached, laterite soils are common we found that rock powders also increased productivity at times more than conventional nitrogen-phosphorous-potassium fertilizers.

Over the past decade I have been involved with colleagues in Portugal on some of their problems of soil erosion. In some of the large hydroelectric dams, soil erosion was rapidly causing the reservoirs to fill with fine mud. When we studied the nature of this mud we found large concentrations of plant nutrients and a high concentration of fine clay particles, the most easily eroded soil component. In extensive tests, we found that the reservoir sediments when added to soil, increased bioproductivity more than common fertilizers. Again the waste had value and its use solved several problems (see Fonseca et al. [3]). Fine clay minerals very efficiently absorb water on their OH concentrated surfaces. We also found that the soils ability to hold water was increased by their addition in part, reducing the need for massive irrigation (see Fonseca et al. [3]).

Examples of such uses of waste abound! There are few wastes which do not have useful applications if their chemistry and all other properties are well quantified. In Europe there are many projects to design objects like cars where all parts are easily recycled. Front end quality control is the secret of efficient recycling.

And among the use of dangerous materials must be listed the overuse, unnecessary use, of herbicides and pesticides. Years ago I was impressed that in most of Switzerland it was illegal to use such things in an urban environment. What is wrong with a dandelion? And recent notes in both the journals Nature and Science report that problems like Parkinson’s disease may be related to such compounds! There are some old rules: all living things have many common bio-organic characters and as many have stressed, if a material kills any advanced organism, it will probably be dangerous for all. This is why in the U.K. they use the term biocides.

8 Concluding statements

When one examines the prospects for a positive future in various nations, it is clear that this is related to the quality of education for all people, male and female, of all ages. To obtain reliable information I recommend the excellent publications by The Economist, Pocket World in Figures, which is revised every two years (see Profile Books Ltd., London, U.K.). The data clearly shows that quality of life is related to education. We must have universal literacy, numeracy and sciency. In the journal, The Economist (Nov. 22, 2003) they discuss the state of children and females in Cambodia and Afghanistan. The situation is a disaster in their societies dominated by males! Only six percent of girls go to school in Afghanistan. The rich-poor gap is growing!
We can save this world and people can have a high quality of life now and in the future. But all people must understand our life support systems. Yes, many nations must reduce populations for security. In solving almost all the world problems Europe leads. Europe has the lowest birthrates in the world!

References