3/8/91 Manuscript for Submission to Remineralize the Earth

REMINERALIZE THE EARTH TO REDUCE CARBON DIOXIDE

by

Fred B. Wood, IV and Fred B. Wood, III

Computer Social Impact Research Institute

2346 Lansford Ave.

San Jose, CA. 95125 U.S.A.

ABSTRACT

Paleoclimatic data indicate that the Earth is in the late stage of the present interglacial (see Remineralize the Earth, Winter 1991, pp. 32-35),[1] but we are not sure how the natural late interglacial climate process interacts with anthropogenic climate forcing due to greenhouse gas emissions and deforestation. We do know that the climate forcing is unprecedented in magnitude and rate of increase; paleoclimate data suggest that the Earth has not faced such a forcing for several million years and perhaps longer. Climate monitoring and modeling are fraught with uncertainties and complexities, leading to a variety of climate change scenarios. Scientific uncertainties may take years to resolve. In the interim, the prudent course of action is to stabilize and then reduce atmospheric concentrations of greenhouse gases as soon as possible. Soil remineralization can play a significant role by helping to increase the global biomass (e.g., forests and vegetation) which through photosynthesis serves as a major sink that absorbs atmospheric carbon dioxide.

---

*Second of two articles--part one (Remineralize the Earth, Winter 1991, pp. 32-35) discussed the importance of remineralization in the context of glacial-interglacial cycles and need for stronger remineralization programs; part two discusses why remineralization should help stabilize climate by reducing atmospheric carbon dioxide.

**The views expressed are those of the authors and not necessarily those of the CSIRI or other organizations with which the authors are affiliated.

Soil Remineralization and Climate Change

Soil remineralization has not yet been widely accepted in part because it has been caught up in the larger debate over the nature and direction of global climate change. The idea of "fertilizing" or "remineralizing" some forest and agricultural soils with high mineral content glacial or volcanic rock dust has recently attracted attention not only for sustainable ("organic") farming, but as a way to increase vegetation productivity and CO_2 uptake and thereby help stabilize climate.

The scientific rationale for soil remineralization, outlined in part one of this two-part Remineralize the Earth series,[2] is based on paleoclimatic and paleoecological data that indicate: (1) the Earth is presently in the later stage of the current interglacial period; (2) during late interglacial stages, soils are substantially depleted of key minerals due to natural processes; and (3) a primary source of "natural" high mineral content fertilizers is glacial and volcanic rock.

Small-scale organic farmers in the U.S., Europe, and elsewhere have successfully used high mineral content rock dust to improve soil quality and vegetation productivity.[3] It is well established that healthy plants and trees require good soil--with adequate mineral content, organic matter, and microorganism activity--that provides nutrients and makes growth possible. Properly mineralized soil is a necessary but not, of course, by itself a sufficient condition for healthy vegetation. Other factors such as temperature, water, pollution, and urbanization all affect the health of plants and trees.[4]

Scaling soil remineralization up from small farms to large geographic areas should increase vegetation productivity and photosynthesis enough to make a significant contribution to reducing atmospheric CO2, since the global biomass is a major sink for (i.e., absorbs a large amount of) atmospheric CO_2.[5] Remineralization should be an important adjunct to reforestation and sustainable agriculture which, along with renewable energy (including bioenergy) as a direct substitute for fossil fuels, are among the most promising opportunities to help stabilize and then reduce atmospheric CO_2.[6] Remineralization should help improve the health of already established temperate and boreal forests, augment tropical reforestation programs, and complement a wide range of other organic farming techniques (such as crop rotation, conservation tillage, integrated pest and weed control, and low input irrigation).[7] Remineralized forests and farms should be more resistant to the ravaging effects of drought, insects, acid precipitation, fire, and weather extremes, all other things being equal.[8] As an added benefit, remineralization should help improve human health through more nutritious food.[9]

Additional research is needed, however, to analyze remineralization from 3 related perspectives: (1) carbon (and other biogeochemical) cycles of both vegetation and soil, to ensure that atmospheric CO_2 (and other greenhouse gases) indeed would be reduced through remineralization, all other things being equal; (2) energy and environmental requirements, to ensure that the greenhouse costs of the energy and environmental impacts of sourcing, grinding, transporting, storing, and applying the rock dust would not offset the greenhouse reductions anticipated from increased photosynthesis of the remineralized vegetation; and (3) engineering and technical requirements, including pilot tests, to ensure that remineralization is feasible under a range of soil, vegetation, geographic, geologic, and climatic conditions. Analyses of a conceptually similar proposal to fertilize ocean surface waters with iron (and thereby stimulate growth of phytoplankton have identified a significant potential to sequester CO_2 but also possible scientific and practical limitations.[10] But we believe that the odds are much better that large-scale soil remineralization can work and that the logistical problems, however challenging, are much less onerous on land than at sea.

In sum, remineralization should help significantly increase the size and health of the biomass, which in turn should result in greater photosynthesis and a lower level of atmospheric carbon dioxide (or a reduced rate of CO_2 increase), all other things being equal. But to date, the debate over the nature and direction of global climate change has diffused or diverted attention from using soil remineralization to help stabilize carbon dioxide levels.

Need to Stabilize Trace Gas Concentrations

Many global climate researchers emphasize the urgency of stabilizing and then reducing the concentration of trace gases in the atmosphere. These researchers cite the exponential increase in carbon dioxide and other radiatively active trace gases that already are at higher levels of atmospheric concentration than at any time in the last 160,000 years and, quite likely, much longer (probably millions of years).[11] The researchers believe that this increase in trace gases is so large and so rapid that the global climate change will occur on a much faster time scale than an interglacial-glacial transition. Most researchers believe that if left unchecked, the trace gas emissions and subsequent climate change likely will outstrip the ability of natural and human systems to adapt, with severe adverse consequences for the Earth and its inhabitants (plants, animals, and humans). A minority of climate change researchers remain unconvinced that increasing greenhouse gas concentrations pose a serious threat.[12]

Many global climate researchers also agree that trace gas-induced climate change is likely to occur very rapidly--on the scale of years to decades, not centuries to millennia. They cite the growing paleoclimatic, paleooceanographic, and paleoecological evidence that critical shifts in, for example, wind patterns, ocean currents, and vegetation assemblages can occur in just a couple of decades--even though the full transition from interglacial to glacial conditions (and vice versa) takes millennia.[13]

The fact that the atmospheric concentration of carbon dioxide is increasing more than 100 times faster than natural variability indicated in the paleoclimatic record,[14] and at 354 ppm is already well above the peak levels (of 290-300 ppm) recorded during the last two glacial-interglacial cycles, lends credence to this concern.[15] The early part of this recent increase in atmospheric carbon dioxide correlates in time with the widespread clearing of forest lands for agriculture during the 1800s. The latter part of the increase correlates with the rapid increase in fossil fuel consumption and urbanization during the 1900s, augmented by rapid tropical deforestation since the 1950s.

The paleoclimatic record suggests that a significant (e.g., 50 percent) increase or decrease in atmospheric concentration of CO_2 from preindustrial levels could destabilize global climate.[16] We have concluded that the interglacial level of atmospheric CO_2 (around 280-290 ppm for the last 10,000 years, until the agricultural/industrial revolutions) is at a critical and quasi-stable threshold.

For much of the last 1 billion years, atmospheric CO_2 and surface temperature were much higher than at present. Over the last 100 million years, CO_2 and temperature declined to the levels that permitted the onset of the ice ages over the last 2 million years or so (the "Quaternary"). During the Quaternary, paleoclimatic data suggest many glacial-interglacial cycles, each roughly 100,000 years long (with a 90,000 glacial period and 10,000 warm interglacial, on the average). The earth is presently in the later stages of the present interglacial (the "Holocene") which commenced about 10,000 years ago.[17] During the Quaternary, CO_2 appears to have ranged from a low of about 200 ppm (during the peak of the glacial periods) to a high of about 300 ppm (during the peak of the interglacial periods).

In sum, it appears that the earth's climate has somehow arrested the long-term decline in CO_2 and temperature to achieve a quasi-stable state that oscillates between glacial and interglacial levels. The earth's climate has been stable (or quasi-stable) during the Quaternary apparently because somehow the negative feedbacks in the system dominate and are self-correcting, keeping the climate from getting too cold and glaciated or from getting too warm. However, we have concluded that the climate system is likely to become unstable if pushed very far outside of the Quaternary range.

The feedback effects of stratospheric aerosols (from volcanoes), tropospheric aerosols (from pollution), clouds, and the like, still leave much uncertainty about climate change. Nonetheless, the available evidence from the Phanerozoic (last 600 million years), Quaternary (2 million years), and Holocene (10,000 years) is consistent with our central hypothesis--that major changes in atmospheric CO_2 are likely to destabilize climate--even though the climate feedbacks themselves are not well understood.

Our conclusion is that the prudent approach is to stabilize and then reduce CO_2 (and other radiatively-active trace gases) as soon as possible, at least until we have much better knowledge about precisely what level of elevated CO_2 would be likely to destabilize the climate system. (There is the theoretical possibility that depressed CO_2 could likewise destabilize climate, but this appears at present to be a very unlikely prospect.) We also base our conclusion on the paleoclimatic record which strongly suggests that major climatic shifts can take place in as little as 20 years, and that CO_2 at 354 ppm is already about 25 percent above preindustrial interglacial levels (and 75% above glacial levels). Since we do not know exactly what CO_2 levels might trigger major (and possibly irreversible) climatic change, and by the time we find out it may be too late to take preventive action, the prudent course is to first stabilize, then reduce.

Remineralizing Under Climate Uncertainty

Soil remineralization can be implemented under a wide range of climate change scenarios. It may take many years to resolve climate complexities and uncertainties, but remineralization can be carried out much sooner. As discussed in part one of this two-part series,[18] as soil remineralization advocates, we must redouble our efforts to demonstrate and communicate to the research and policy communities that remineralization works.

Overall, the risks of climate change appear to be high, and the outcome seems much more likely to be harmful than beneficial--and possibly even catastrophic--to human civilization. Over the last few thousand years, climate changes of comparable (or perhaps lesser) magnitude have severely disrupted regional or continental human settlement patterns, with major impacts on food, water, health, and the viability of tribes, communities, and even nation-states and empires.[19]

Many climate researchers agree that one of the greatest risks is increased climate variability. The recent rash of record high and low temperatures (and precipitation)[20] cannot yet be clearly attributed to anthropogenic forcing. But these climate extremes provide a foretaste of what might be expected if the global climate were to be sufficiently destabilized. Many ecological and agricultural systems would be severely threatened if weather extremes continued for several years in a row. Indeed, short-term climate variability may turn out to be as or more important than long-term annual averages.

Thus it is incumbent that, as soil remineralization advocates, we urge remineralization action now to help stabilize atmospheric CO_2 and reduce the risks and mitigate adverse impacts under a range of climate change scenarios. We need to present soil remineralization as one of those actions that will be viable and helpful, regardless of what the climate future may hold. In essence, we need to decouple soil remineralization from any particular climate change scenario, in order that remineralization may go forward years (and perhaps decades) before the climate debate ultimately may be settled. We have no time to lose. If we wait until climate uncertainties are resolved, it may well be too late to avert harmful consequences for human civilization.

REFERENCES

1 For an excellent overview of glacial-interglacial cycles during the quaternary (last 2 million years), see G. Kukla, "The classical European glacial stages: correlation with deep-sea sediments," Transactions of the Nebraska Academy of Sciences 6:57-93, 1978.

2 F.B. Wood, IV and F.B. Wood, III, "Soil Remineralization for sustainable agriculture and climate stabilization: a call for action," Remineralize the Earth, Winter 1991, pp. 32-35.

3 Ibid., and references cited therein. Also see P. Tompkins and C. Bird, Secrets of the Soil (New York: Harper and Row, 1989).

4 Ibid.

5 See, for example, J.M Adams et al., "Increases in terrestrial carbon storage from the Last Glacial Maximum to the present," Nature 348:711-714, 1990.

6 See R.A. Houghton, "The future role of tropical forests in affecting the carbon dioxide concentration in the atmosphere," Ambio 19:204-209, 1990; T.J. Goreau, "Balancing atmospheric carbon dioxide," Ambio 19:230-236, 1990; U.S. Congress, Office of Technology Assessment Changing by Degrees: Steps to Reduce Greenhouse Gases (Washington, DC: U.S. Government Printing Office, February 1991); and R. Senanayake, "Sustainable agriculture: the role of soil," topic 5 in data.farmnet computer conference on ECONET, Mar. 16, 1990.

7 For general discussion, see, for example, K. Caesar, "Developments in crop research for the third world," Ambio 19:353-357, 1990; F. Le Tacon and J.L. Harley, "Deforestation in the tropics and proposals to arrest it," Ambio 19:372-378, 1990; and S.T. Gower and J.H. Richards, "Larches: deciduous conifers in an evergreen world," BioScience 40:818-826, 1990; U.S. Congress, Office of Technology Assessment, Enhancing Agriculture in Africa: A Role for U.S. Development Assistance (Washington, DC: U.S. Government Printing Office, September 1988).

8 See Remineralize the Earth, Winter 1991.

9 See, for example, A.G. Cairns-Smith, Genetic Takeover and the Mineral Origins of Life (Cambridge: Cambridge University Press, 1982); W.H. Calvin, The Ascent of Mind: Ice Age Climates and the Evolution of Intelligence (New York: Bantam Books, 1990); P. Tompkins and C. Bird, Secrets of Life, op.cit.; Remineralize the Earth, Winter 1991.

10 See J.M. Martin et al., "Iron deficiency limits phytoplankton growth in Antarctic waters," Global Biogeochemical Cycles 4:5-12, 1990; Dugdale and Wilkerson, "Iron addition experiments in the Antarctic: a reanalysis," Global Biogeochemical Cycles 4:13-19, 1990; T.H. Peng and W.S. Broecker, "Dynamical limitations on the Antarctic iron fertilization strategy," Nature 349:227-229, 1991; OTA, Changing by Degrees, op.cit., App. 2-A, "Fertilizing the Oceans with Iron," pp. 72-73.

11 See J.M. Barnola, D. Raynaud, Y.S. Korotkevich, and C. Lorius, "Vostok ice core provides 160,000-year record of atmospheric CO_2," Nature 329:408-414, 1987; IPCC, Scientific Assessment of Climate Change, op.cit.; and R.A. Berner, "Atmospheric carbon dioxide over Phanerozoic time," Science 249:1382-1386, 1990.

12 See, for example, R.S. Lindzen, "Some coolness concerning global warming," Bulletin of the American Meteorological Society 71:288-299, 1990; R.E. Newell and T.G. Dopplick, "Questions concerning the possible influence of anthropogenic CO_2 on atmospheric temperature," Journal of Applied Meteorology 18:823-825, 1979; H.W. Ellsaesser, "The climatic effect of CO_2: a different view," Atmospheric Environment 18:431-434,

1984; H.W. Ellsaesser, "A different view of the climatic effects of CO_2--updated," August 1989 preprint, Lawrence Livermore National Laboratory, P.O. Box 808, Livermore, CA 94550; P.J. Michaels, "The greenhouse effect and global change: review and reappraisal," International Journal of Environmental Studies 36:55-71, 1990; S.B. Idso, Carbon Dioxide and Global Change: Earth in Transition (Tempe, AZ: IBR Press, 1989); and F. Seitz, R. Jastrow, and W.A. Nierenberg, Scientific Perspectives on the Greenhouse Problem (Washington, DC: George C. Marshall Institute, 1989).

13 See W.S. Broecker, "Unpleasant surprises in the greenhouse?" Nature 328:123-126, 1987; W. Dansgaard, "Past climates and their relevance to the future," in H. Flohn and R. Fantechi (eds.), The Climate of Europe: Past, Present, and Future (Boston, MA: D. Reidel, 1984), pp. 208-239; and G. Woillard, "Abrupt end of the last interglacial in North-East France," Nature 281:558-562, 1979.

14 Atmospheric CO_2 is currently increasing at about 1.75 parts per million (ppm) per year, compared to roughly 0.01 ppm/year during the last 3 glacial-interglacial transitions, based on our analysis of data in J.M. Barnola et al., "Vostok ice core," op.cit., and C. Lorius et al., "The ice-core record: climate sensitivity and future greenhouse warming," Nature 347:139-145, 1990.

15 For an excellent synthesis of CO_2 trends, see W.M. Post, T.-H. Peng, W.R. Emanuel, A.W. King, V.H. Dale, and D.L. DeAngelis, "The global carbon cycle," American Scientist 78:310-326, 1990; also see A. Neftel, H. Oeschger, J. Schwander, B. Stauffer, and R. Zumbrunn, "Ice core sample measurements give atmospheric CO_2 content during the past 40,000 yr.," Nature 295:220-223, 1982. Note that earlier analyses of ocean floor sediments suggested a previous CO_2 peak of about 350 ppm (see N.J. Shackleton, M.A. Hall, J. Line, and C. Shuxi, "Carbon isotope data in core V19-30 confirm reduce carbon dioxide concentration in the ice age atmosphere," Nature 306:319-322, 1983). But more direct measurements of the CO_2 content of air bubbles trapped in ice cores indicate a CO_2 peak of 290-300 ppm (see Barnola et al., "Vostok ice core," op.cit.; and C. Lorius et al., "The ice-core record," op.cit.).

16 See Berner, "Atmospheric carbon dioxide over Phanerozoic time," op.cit.; M.I. Budyko, A.B. Ronov, and A.L. Yanshin, History of the Earth's Atmosphere (Berlin: Springer-Verlag, 1987); M.I. Budyko, Global Ecology (Moscow: Progress Publishers, 1980); M.I. Budyko, Climatic Change (Washington, DC: American Geophysical Union, 1977); M.I. Budyko, G.S. Golitsyn, and Y.A. Izrael, Global Climate Catastrophes (New York: Springer-Verlag, 1988).

17 See Wood and Wood, "Soil remineralization: a call for action," op.cit.

18 Wood and Wood, "Soil remineralization: a call for action," op.cit.

19 See, for example, H.H. Lamb, Changing Climate: Present, Past, and Future (London: Metheun, 1977); S.H. Schneider and R. Londer, The Coevolution of Climate and Life (San Francisco, CA: Sierra Club Books, 1984); and R.A. Bryson, "Civilization and rapid climate change,"

Environmental Conservation, Vol. 15, 1988, pp. 7-15.

20 See National Oceanic and Atmospheric Administration, Weekly Climate Bulletin, op.cit., for numerous examples of U.S. and global climate extremes.