

complexes I and II, which are components of the electron transport chain that generates energy by oxidative phosphorylation.

Wegrzyn *et al.* determined that in a subset of mouse B lymphocytes devoid of Stat3, oxidative phosphorylation was reduced, a defect attributable to the diminished activity of complexes I and II. That the number of mitochondria and their content of the proteins that constitute complexes I and II were not altered in Stat3-null cells suggests that Stat3 regulates the activity, as opposed to the absolute amount (as would be expected for transcriptional regulation), of complexes I and II.

The expression of Stat3 in these otherwise Stat3-null cells restored oxidative phosphorylation, and this rescue of mitochondrial function did not require the DNA binding domain, the dimerization motif, or the tyrosine phosphorylation site that controls Stat3 nuclear localization and transcriptional activity, consistent with a transcription-independent role for Stat3. By contrast, the conserved serine phosphorylation site on Stat3 was important: Expression of Stat3 with a mutation that prevented phosphorylation of this serine did not

produce the rescue effect, whereas a phosphomimetic mutant at this site did. It remains to be determined whether Stat3 is unique among STAT proteins in localizing to and regulating mitochondria.

The nontranscriptional function of Stat3 in mitochondria raises many questions about its precise role in the organelle. For instance, although the results of Wegrzyn *et al.* reveal the absolute requirement for Stat3 to maintain normal mitochondrial function, they do not speak directly to the potential role for Stat3 in the physiologic regulation of cellular respiration. Presumably, specific signaling pathways, such as those that regulate the serine phosphorylation of Stat3, modulate Stat3-dependent control of cellular respiration (see the figure). Whether the control of mitochondrial localization, complex I/II association, or some other step might underlie such regulation remains unclear, however.

Although it is tempting to speculate that cytokines use Stat3 to coordinately regulate transcription and respiration, the inhibition of Stat3-dependent transcription by GRIM-19 suggests that the opposite—Stat3 performs

each job at the expense of the other—is just as likely. Also, because many cytokine-independent intracellular signaling proteins (such as protein kinase C isoforms and mitogen-activated protein kinases) promote the serine phosphorylation of Stat3 (2), cytokines may not be the only, or even the major, controllers of Stat3-modulated oxidative phosphorylation.

Although many questions will take substantial research to work out, the newly discovered mitochondrial function for Stat3 has the potential to dramatically expand the way we think about the roles of STAT proteins, as well as how canonical cellular signaling pathways may control cell energetics.

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## GEOLOGY

# Heavy Metals or Punk Rocks?

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At the recent World Copper Congress in Santiago, Chile, Rio Tinto's chief executive for copper, Bret Clayton, reported that copper consumption is expected to double over the next two decades (1); demand for other metals is expected to parallel this trend. These projected metal needs cannot be satisfied with known ore bodies. To locate new deposits, minerals exploration programs require robust genetic models for the formation of economic accumulations of metals. On page 764 of this issue, Wilkinson *et al.* (2) elucidate one of the least understood aspects of ore formation: the concentration of metals in hydrothermal solutions that deposited the ores.

Fluid inclusions provide the best available tool for determining the physical and chemical conditions during ore formation (3). These microscopic samples (~5 to 50  $\mu\text{m}$  in diameter) of the ore-forming fluid are trapped in ore and non-ore minerals during

mineralization; they thus record the temperature, pressure, and composition of the ore-forming fluid. Advanced microanalytical techniques allow individual fluid inclusions to be analyzed to determine ore metal concentrations (4–6).

Wilkinson *et al.* now report unusually high metal contents of hydrothermal fluids from two ore districts containing sediment-hosted zinc-lead deposits, based on microanalysis of fluid inclusions. Other recent studies of fluid inclusions from copper (7) and gold (8) deposits also found much higher metal concentrations than would have been predicted on the basis of experimental data or theoretical models. If confirmed by further studies, these results have important implications for both the duration of the ore-forming process and the amounts of ore fluids needed to generate world-class ore deposits. This information is of crucial importance for understanding ore genesis, given that the duration of ore-forming systems is one of the major unknowns related to the formation of mineral deposits (9).

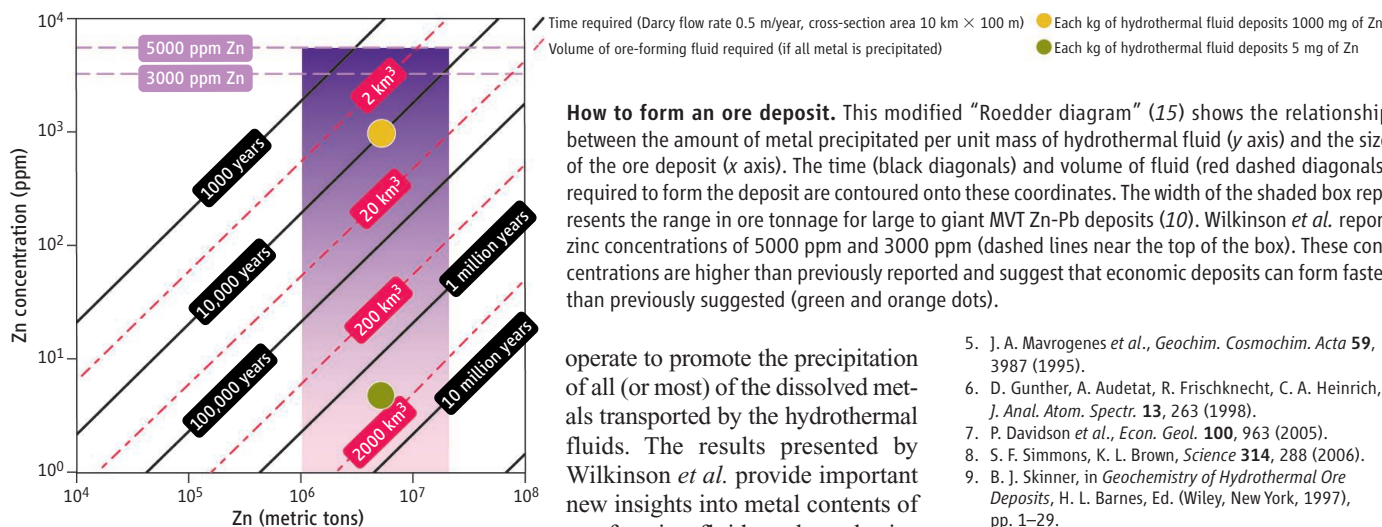
Average continental crust contains about 70 ppm zinc (Zn) and 12.5 ppm lead (Pb). In

Meeting the world's demand for metals such as copper and zinc may be aided by recent insights into the formation of ore deposits.

contrast, average ore grades in Mississippi Valley-type (MVT) Zn-Pb deposits similar to those studied by Wilkinson *et al.* typically are about 6% Zn and 2% Pb by weight, representing enrichment factors of about 850 and 1600, respectively. Thus, metals must be scavenged from a large volume of rock with average crustal metal values and concentrated into a much smaller rock volume to generate economic deposits. For example, large to giant MVT deposits contain on the order of  $10^6$  to  $2 \times 10^7$  metric tons combined Zn + Pb (10), with an average Zn:Pb ratio of ~3.

Garven (11) modeled the fluid-flow history associated with formation of a large MVT Zn-Pb deposit in Pine Point, Canada, and concluded that the total hydrothermal fluid discharge through the mineralized area was  $5 \times 10^6 \text{ m}^3 \text{ year}^{-1}$ . Garven assumed that 5 mg of zinc precipitated per kilogram of solution that flowed through these rocks and concluded that it would take from 0.5 to 5.0 million years to form the deposits, with Darcy flow rates (12) of 1 to 5 m  $\text{year}^{-1}$ . Similar durations for ore formation (0.3 million years) have been estimated for the MVT deposits in

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the Upper Mississippi Valley district of the United States (13).

Flow rates and duration of the ore-forming process reported by Garven (11) require total hydrothermal fluid volumes ranging from 2500 to 25,000 km<sup>3</sup> over the lifetime of the ore-forming system. Similar volumes of fluid would be required to form other large to giant MVT deposits if each kilogram of fluid only precipitates a few milligrams of metal. However, if the metal content of the ore-forming fluid is considerably higher, as suggested by Wilkinson *et al.*, then both the amount of fluid required and the duration of the ore-forming event would be reduced by orders of magnitude (see the figure). For example, if each kilogram of hydrothermal fluid deposited 10<sup>3</sup> mg of Zn (orange dot in the figure), then Pine Point and similar deposits could have formed in about 10<sup>4</sup> years from a few cubic kilometers of hydrothermal fluid, compared to the millions of years and hundreds of cubic kilometers of fluid required assuming that each kilogram of hydrothermal fluid deposited 5 mg of Zn (green dot in the figure).

The results presented by Wilkinson *et al.* further highlight the importance of depositional processes in the formation of economic occurrences of metals. Most ore geologists now agree that fluids with metal contents sufficient to produce economic mineralization are relatively common (14), and that it is the lack of a suitable depositional mechanism that often limits ore formation. Temperature decrease alone cannot be the dominant mechanism, because the solubility of most metals in most hydrothermal fluids decreases by only a small amount over the temperature range determined for most deposits. Thus, other processes—such as boiling or immiscibility, fluid mixing, or fluid-rock interactions—must

operate to promote the precipitation of all (or most) of the dissolved metals transported by the hydrothermal fluids. The results presented by Wilkinson *et al.* provide important new insights into metal contents of ore-forming fluids and emphasize the need for continued research to constrain the amounts of hydrothermal fluids required to form world-class ore deposits and the duration of the ore-forming events.

#### References and Notes

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## MATERIALS SCIENCE

# Confined Polymers Crystallize

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Squeezing very thin polymer layers can cause them to form polymer single crystals that could make plastic films less permeable to gases.

Plastics have been very successful in replacing glass, metals, and wood, in part because they are light and easy to process into complex shapes at high speed and at low cost. However, in applications such as packaging, molded plastics can be at a disadvantage compared with steel, aluminum, and glass because of their relatively high permeability to atmospheric gases such as O<sub>2</sub> and CO<sub>2</sub>. This problem arises because the synthetic polymers that are the main component of plastics are rather randomly organized in the solid state with sufficient spaces between the molecules that allow for gas diffusion. Although the problem can be solved to some

extent by adding less-permeable materials to plastics, ideally it would be desirable to find a way to arrange the long-chain polymer molecules in an orderly way, namely, into crystallites in which the molecules are closely packed. On page 757 of this issue, Wang *et al.* (1) report that very thin layers of a commonly used polymer crystallize through special processing conditions into so-called polymer single crystals, which is surprising given the known difficulties in getting polymers to form crystals.

The focus of most polymer research is on functional properties in emerging areas such as biomedical engineering (2), electronics (3), and energy [for example, plastic solar cells (4)], but the vast bulk of synthetic polymers are used in plastics. Packaging materials

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