CLASS 4A: PLUTONS

IMPORTANT QUESTIONS

What are plutons? What are the different kinds? What is their origin? How are they produced? Where are they located? What are some examples?

Plutons are masses or "bodies" of intrusive (plutonic) rocks such as peridotite, gabbro, diorite and granite. Plutons make up a large part of both the oceanic and continental crust. Many are associated with valuable ore deposits.

Plutons are classified by size, shape and relationship to the surrounding rock ("country rock"). Stocks are masses with outcrop areas less than 100 km^2. There is no implication of vertical extent. Some stocks might be the eroded remnants of sub-volcanic magma chambers. Laccoliths are smaller bodies that are roughly circular in map view and plano-convex lens shaped in cross section. They often occur in groups. Batholiths are large masses with outcrop areas larger than 100 km^2. The vertical extent may range from as little as one kilometer to many kilometers. Large batholiths are compound. That is, they are made of many distinct intrusive bodies. Most batholiths are made of granite or related high-sil;ica rock types.

Dikes are tabular (sheet-like) intrusions that cut across the stratification of the country rock. They can also cut across lava flows. Sills are also tabular intrusive bodies but, in contrast to dikes, lie parallel to strata or lava flows. Dikes and sills may be of almost any size or lithology.

EMPLACEMENT OF BATHOLITHS

One of the classic unsolved problems about plutons is how the liquid magma is emplaced. How is space created to accomodate the magma? What happened to the rock that formerly occupied the batholith's space? Debate over this problem has raged for two hundred years and shows no sign of ending anytime soon.

STOPING

One suggested mechanism of emplacement is called "stoping" (with a long "o") after an old mining term. In this process the magma moves upward as joint blocks from the roof of the magma chamber break off and sink to the bottom of the magma chamber. The light magma ascends while the heavier country rock sinks. During its ascent the magma cools, loses volatiles, starts to freeze (crystalizes), increases in viscosity and stalls. Eventually erosion may expose the pluton.

There are at least three problems with stoping as a universal emplacement mechanism. One is that some magmas such as gabbro may actually be denser than some country rocks. In this case the blocks of country rock would not sink. A second problem is why the whole roof of a huge magma chamber doesn't collapse all at once. What holds the roof up? A third difficulty is that no magma bodies of batholithic size have been detected in the modern world.

DIAPIRS

Another suggested emplacement mechanism visualizes big magma bodies as "diapirs" than rise upward because the magma is lighter than the country rock. The process is considered analogous to the well-known diapiric ascent of masses of rock salt, mud and shale. In contrast to stoping, we imagine the magma rising as a big "blob" that pushes aside the country rock to make room for the magma. The process is similar to the rise of an air bubble through oil or shampoo.

One objection to this explanation is that no huge magma blobs have been detected with the geophysical techniques so effective in finding groundwater or oil and gas; the blobs don't seem to exist. Many batholiths vary in composition from place to place whereas one would expect a blob to become well mixed as it moves. Finally the margins of many plutons cut across the stratification of the country rock. This contradicts the diapir model which implies that the country rock is squashed out of the way, thus producing a foliation (parallel orientation of platey minerals like mica) parallel to the contact.

BALLOONING

This model assumes that small amounts of magma are steadily injected into a stationary but expanding magma chamber. Here the magma chamber grows like an inflating balloon, actively pushing the country rock out of the way. The basic evidence for this mechanism is the existence of foliation parallel to the contact in both the country rock and the pluton.

One problem with this model is the absence of a clear mechanism to prevent the magma body from rising due to its low density. Another problem is the presence of cross-cutting contacts around many plutons.

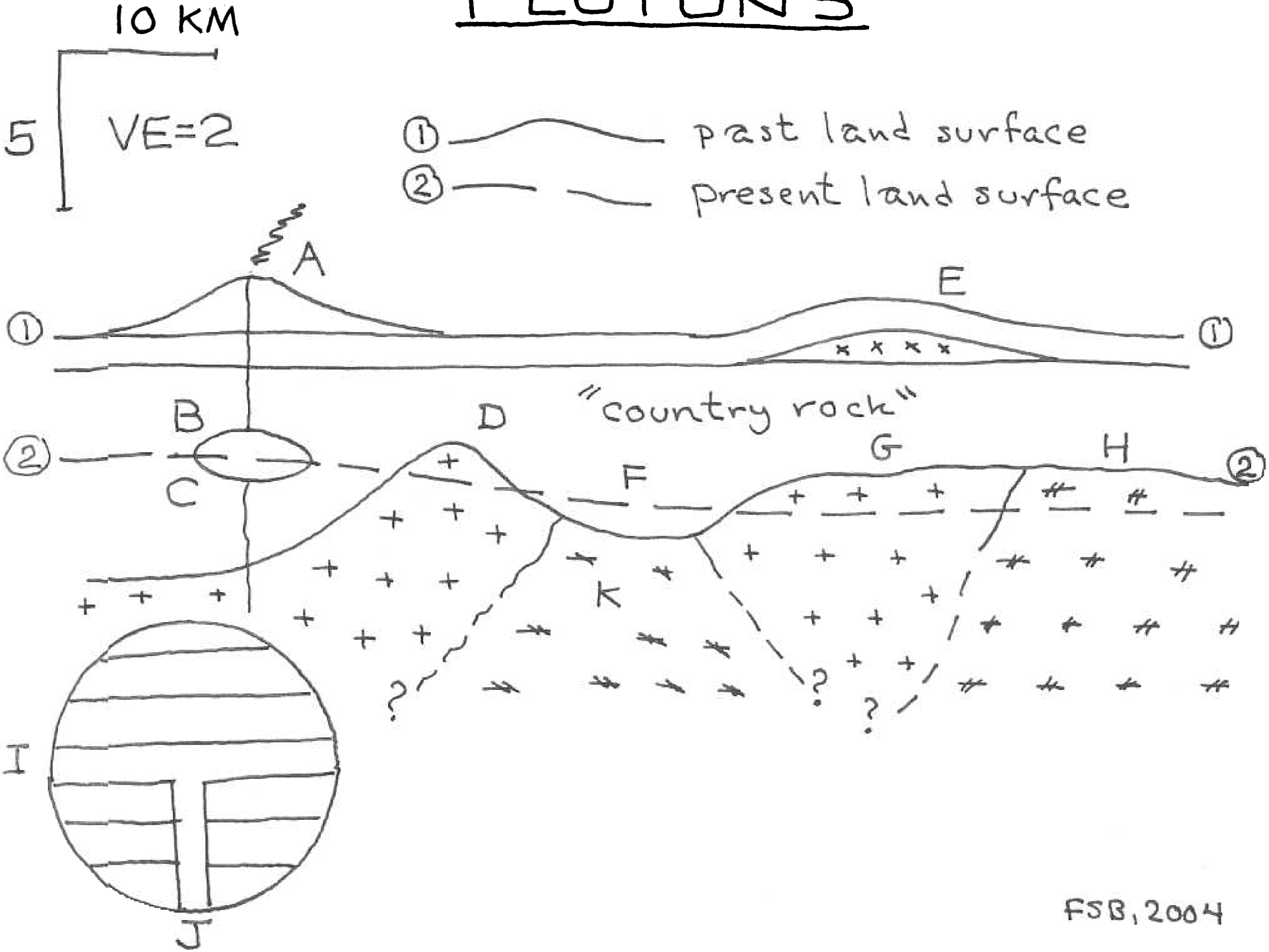
COMPOSITE BATHOLITHS: DIKES AND SILLS

A fourth model starts by claiming that, although batholiths are large, they are made of little pieces. In that case the batholith is formed by successive emplacement of small dikes and sills that easily penetrate small cracks in the growing pluton. Cooling for a long, long time allows recrystallization of the plutonic rock thus erasing evidence of the separate dikes and sills. Evidence for many separate intrusions is given by the wide range in radiometric dates in a batholith. This contrasts with the other models in which the ages are uniform or simply increase from the center to the edges.

SUMMARY

The emplacement of batholiths and other large plutons has been “explained” by several models. Part of the controversy is probably due to different depths of emplacement and depths of exposure of batholiths around the world. We may have been trying to force-fit models where they don’t belong and trying to oversimplify a very complex process. It’s up to your generation to harmonize these conflicting views.

PLUTONS



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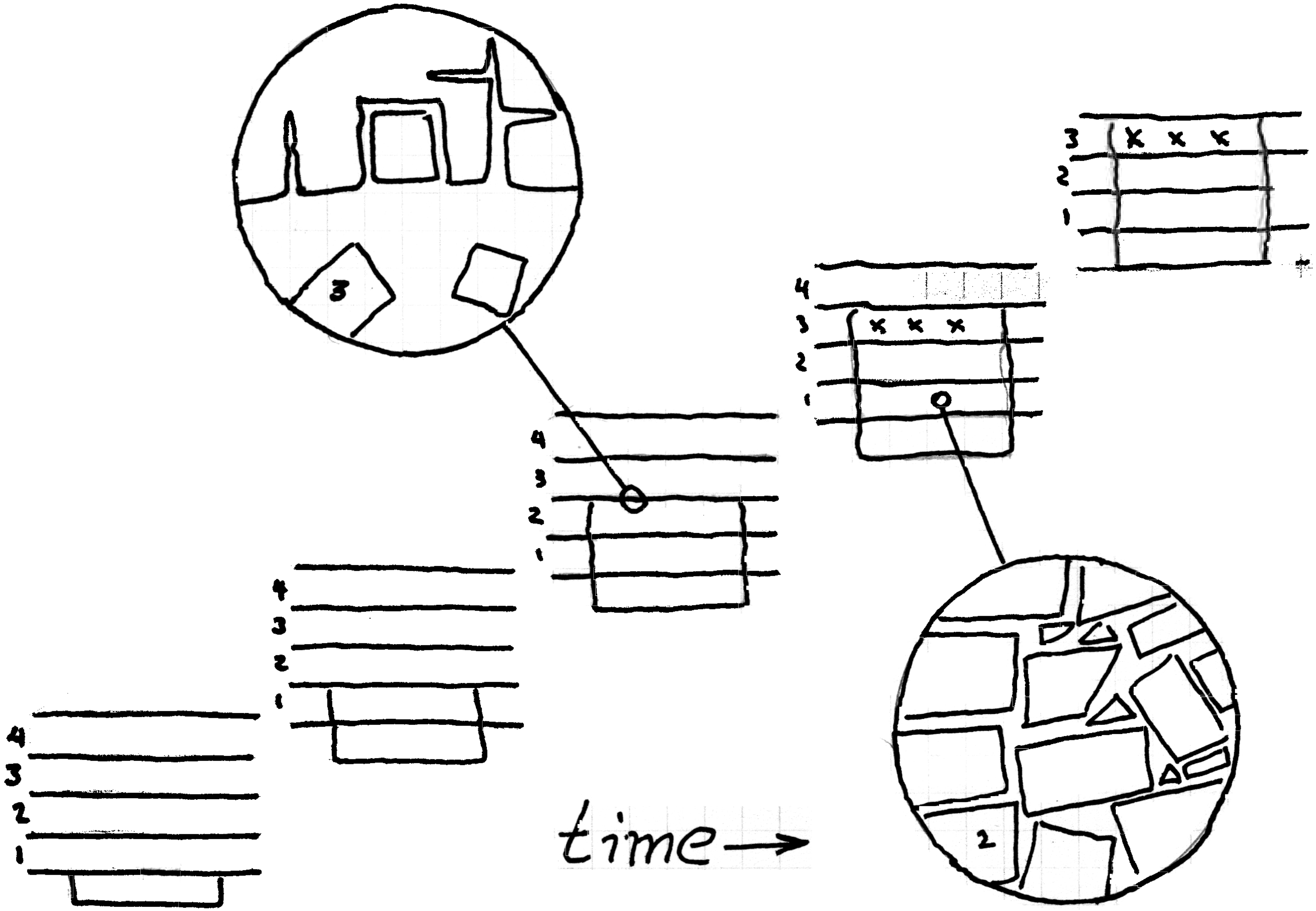
STOPING



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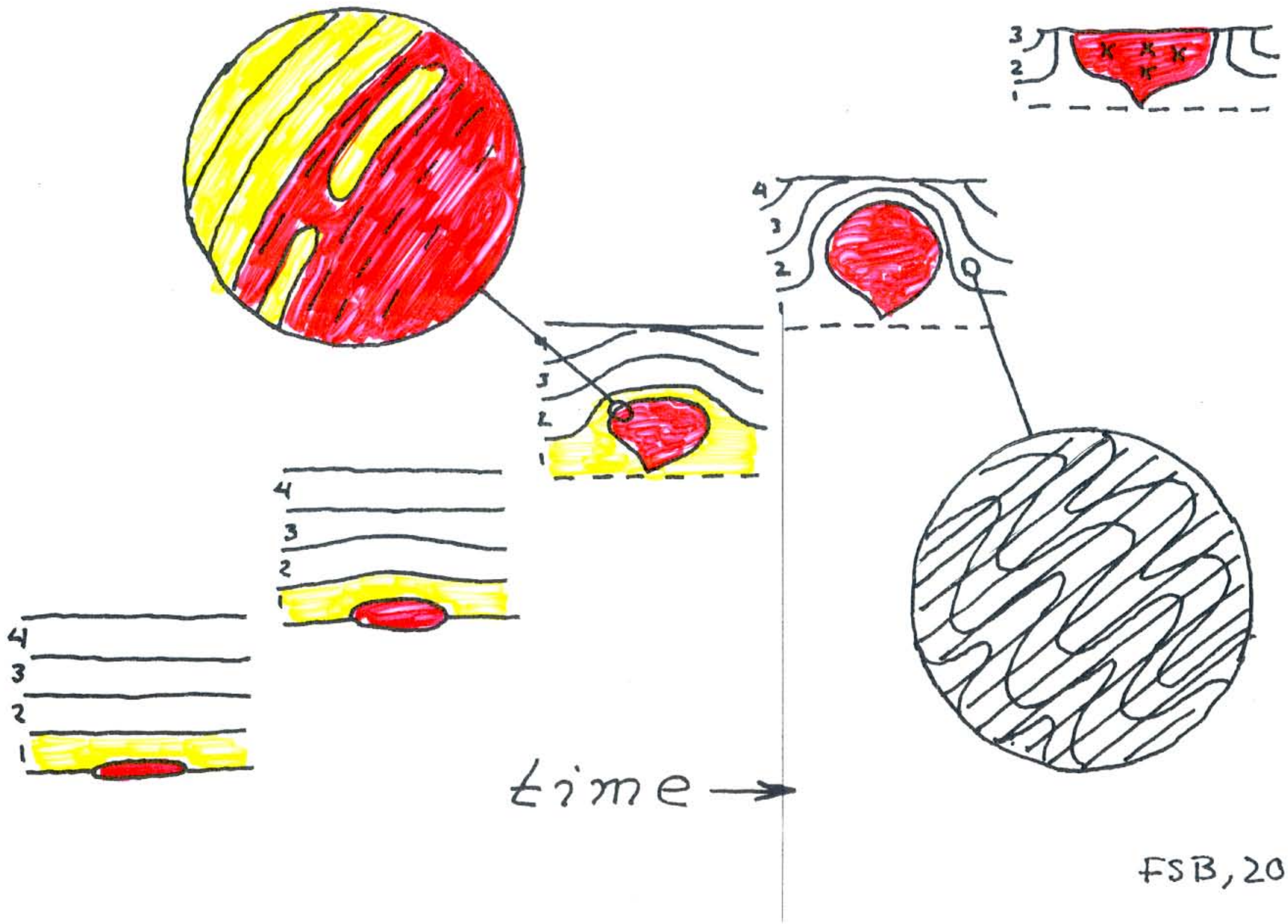
ASCENT OF DIAPIR



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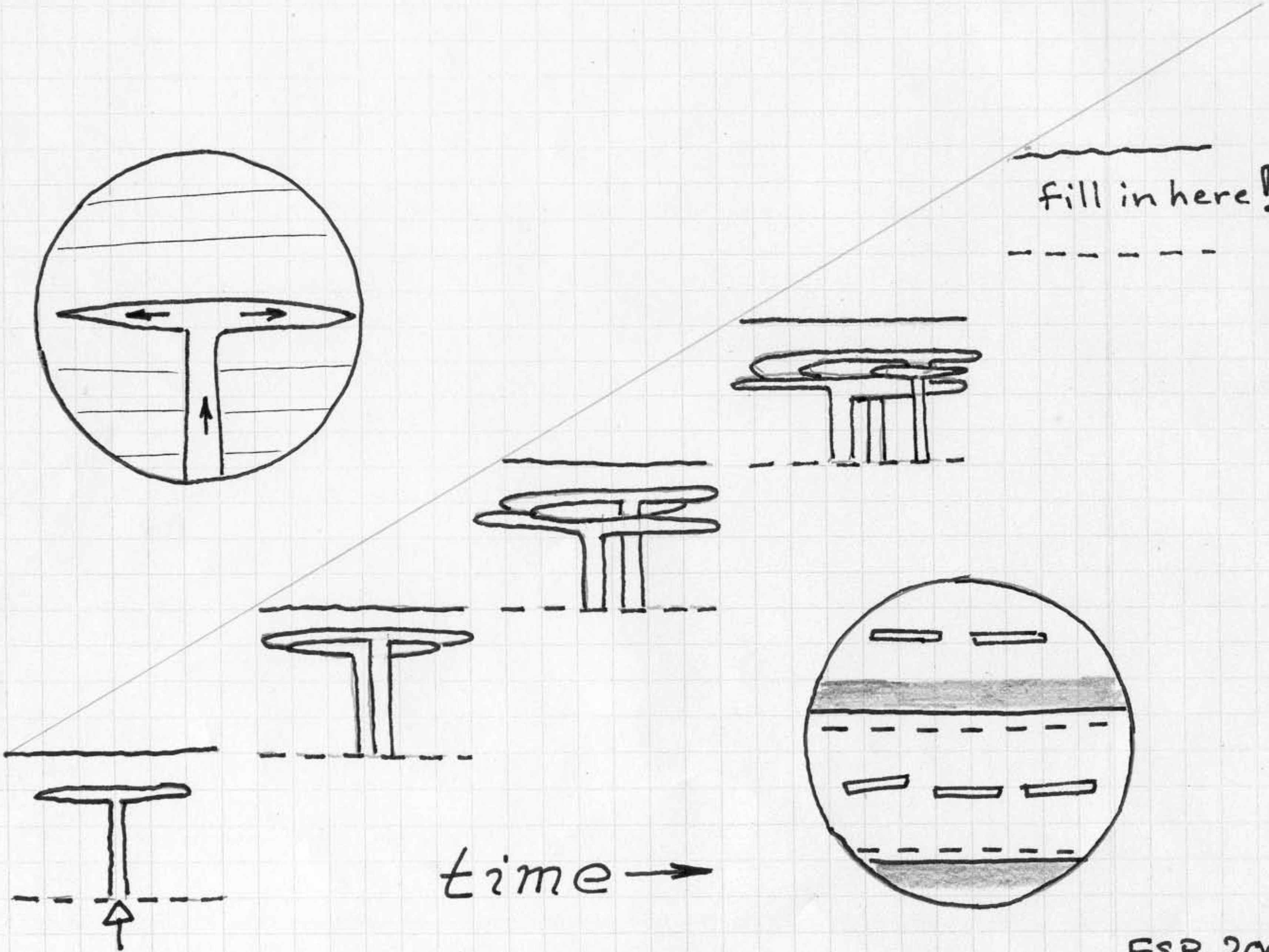
DIKES AND SILLS



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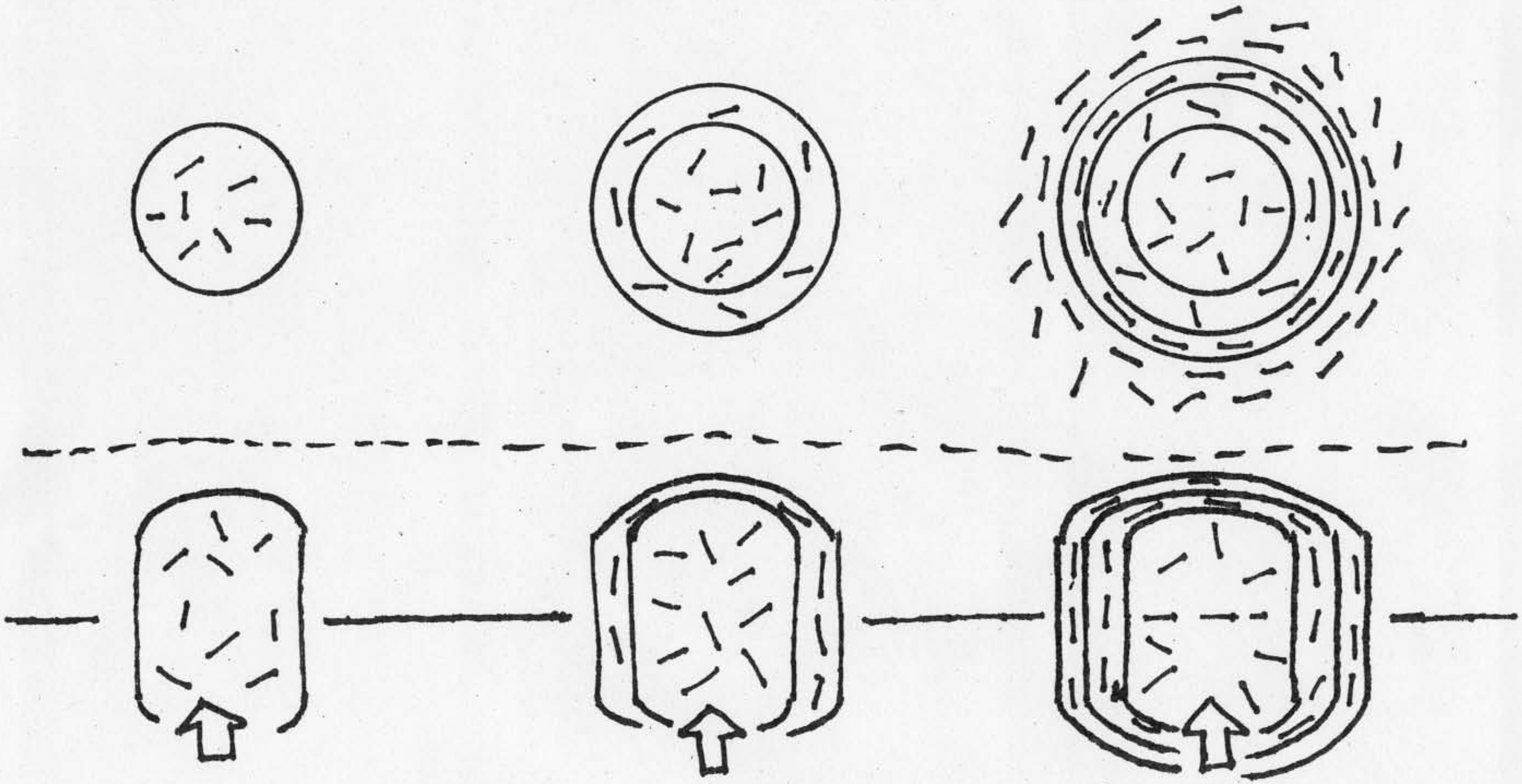
"BALLOONING"



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