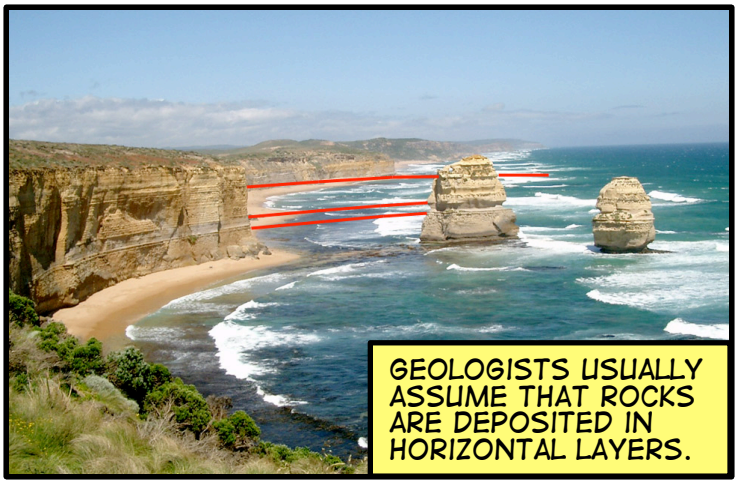
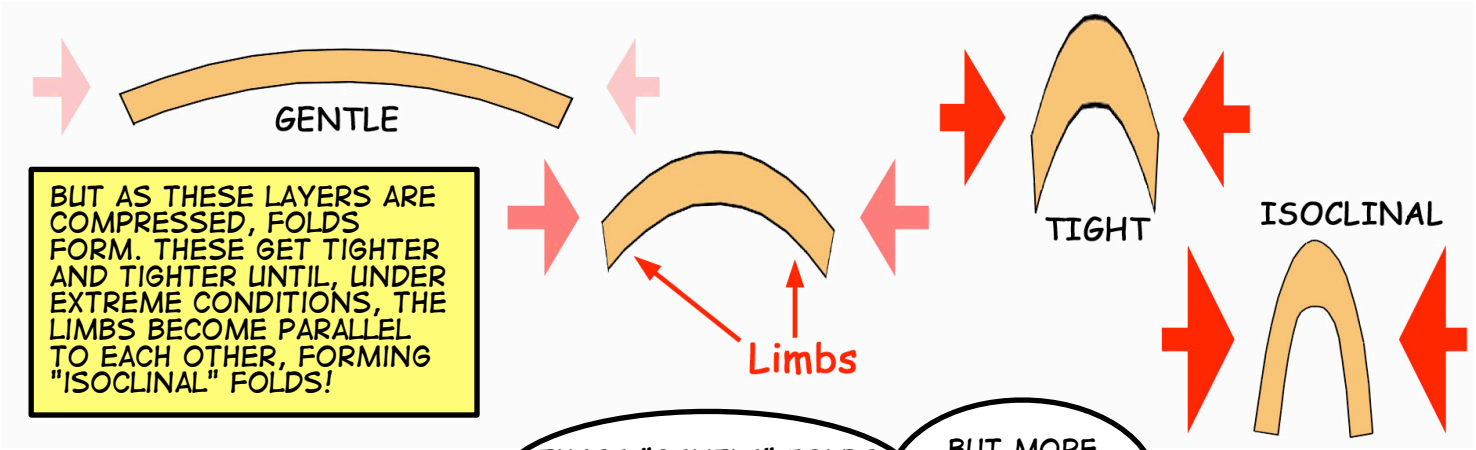
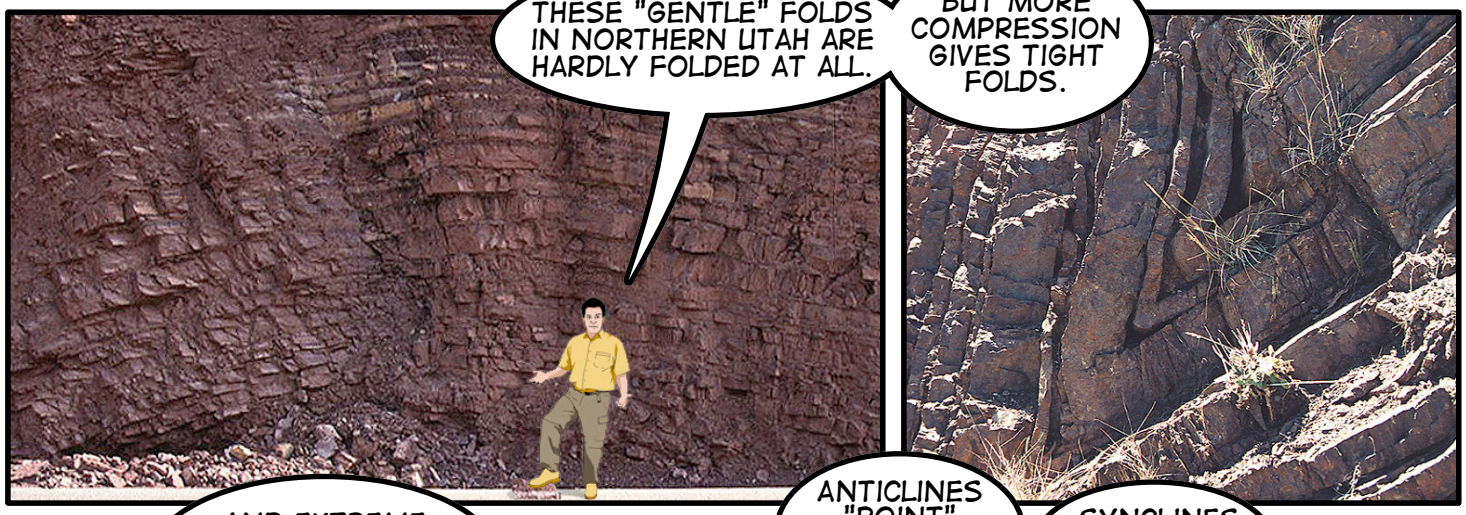
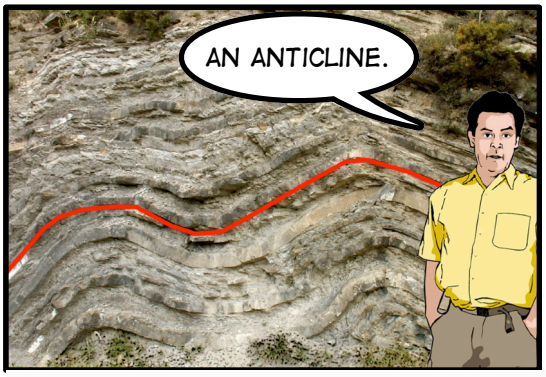

PART 2
SO HOW DO ROCKS BEND?

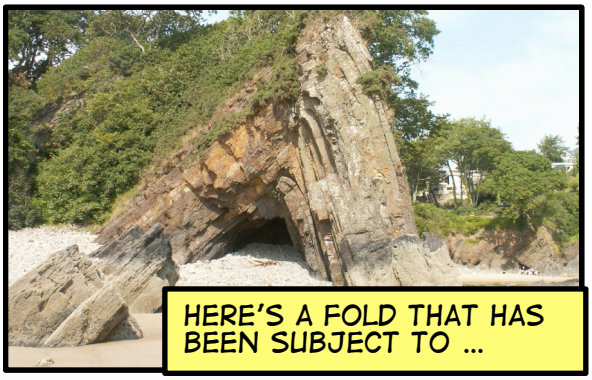

GEOLOGISTS USUALLY ASSUME THAT ROCKS ARE DEPOSITED IN HORIZONTAL LAYERS.


GENTLE
BUT AS THESE LAYERS ARE COMPRESSED, FOLDS FORM. THESE GET TIGHTER AND TIGHTER UNTIL, UNDER EXTREME CONDITIONS, THE LIMBS BECOME PARALLEL TO EACH OTHER, FORMING "ISOCLINAL" FOLDS!
Limbs
TIGHT
ISOCLINAL


THESE "GENTLE" FOLDS IN NORTHERN UTAH ARE HARDLY FOLDED AT ALL.
BUT MORE COMPRESSION GIVES TIGHT FOLDS.


AND EXTREME SQUASHING GIVES PARALLEL LIMBS – ISOCLINAL FOLDS.
ANTICLINES "POINT" UPWARDS, AND...
SYNCLINES POINT DOWN.
AND NEXT TO EVERY SYNCLINE, THERE'S ...





HERE'S A FOLD THAT HAS BEEN SUBJECT TO ...

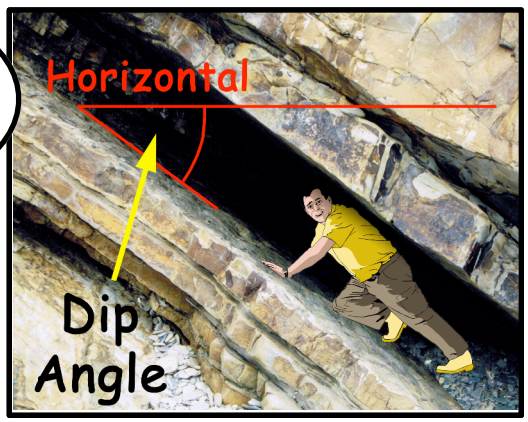
ONLY A MODERATE AMOUNT OF DEFORMATION. FURTHER DEFORMATION CAN MAKE THE FOLDS BECOME INCLINED BY PUSHING THEM OVER.

THIS SYNCLINE IS "INCLINED."

AND THIS FOLD IS "RECUMBENT."

WHEN THE FOLD IS FULLY PUSHED ALL THE WAY OVER, ON TO ITS SIDE LIKE THIS, IT BECOMES HARD TO SAY IF ITS AN ANTICLINE OR A SYNCLINE.

THIS BRINGS UP AN AMBIGUITY THAT WE'LL RETURN TO LATER.

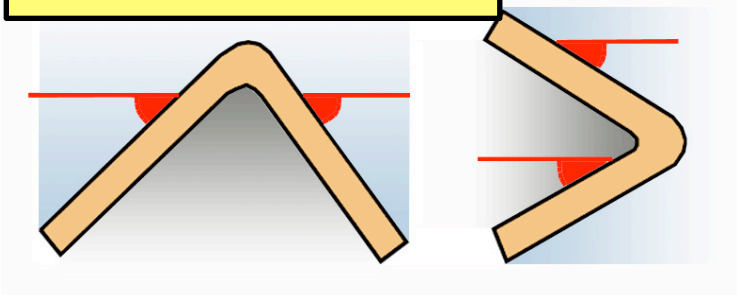


WE DEFINE THE DIP AS THE ANGLE BETWEEN HORIZONTAL AND THE "BEDDING."

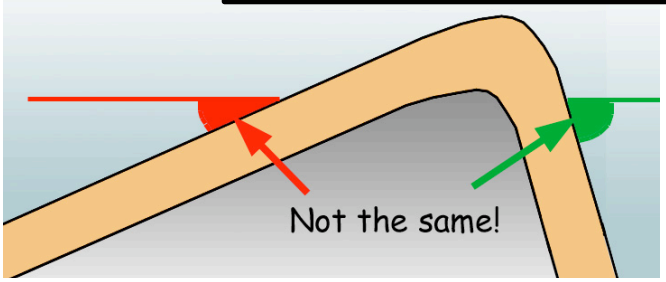
OBVIOUSLY, WHEN THE DIP IS ZERO, THE LAYERS ARE HORIZONTAL.

WHEN IT REACHES 90°, THEY'RE VERTICAL.

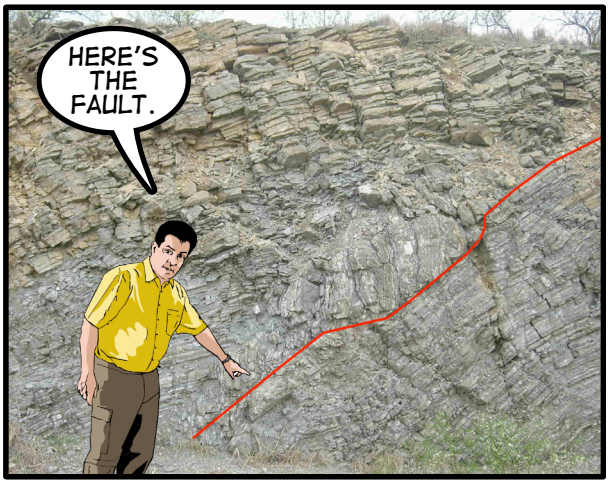
BOTH UPRIGHT & RECUMBENT FOLDS HAVE LIMBS THAT DIP AT ROUGHLY THE SAME ANGLE.



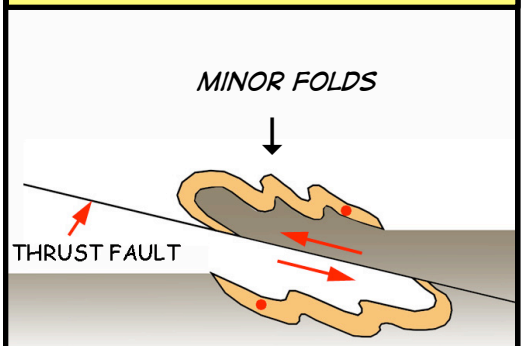
BUT INCLINED FOLDS HAVE LIMBS WITH DIFFERENT DIPS.



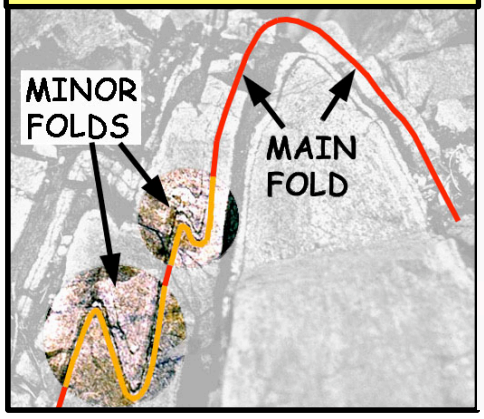
THESE INCLINED AND RECUMBENT FOLDS LOOK RATHER LIKE THE NAPPES THAT WE SAW IN PART 1. NAPPES ARE USUALLY QUITE LARGE STRUCTURES – BUT NOT ALWAYS. HERE IS A SMALL ONE IN THE ARBUCKLE MOUNTAINS OF OKLAHOMA.



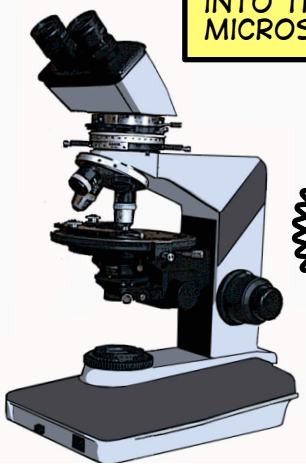
LARGE NAPPES MAY HAVE SMALL FOLDS ON THEIR LIMBS.



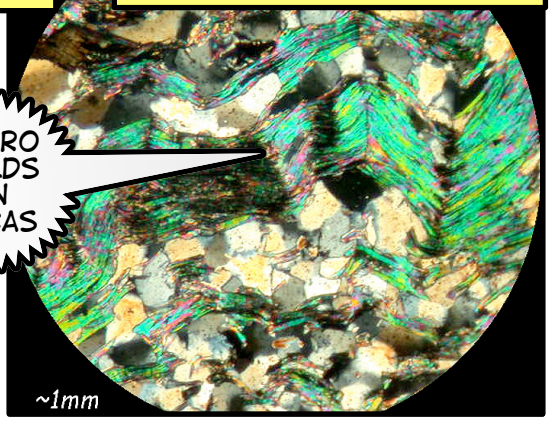
HERE'S A GOOD EXAMPLE FROM METAMORPHIC ROCKS IN UTAH.



GOING DOWN INTO THE MICROSCOPIC...



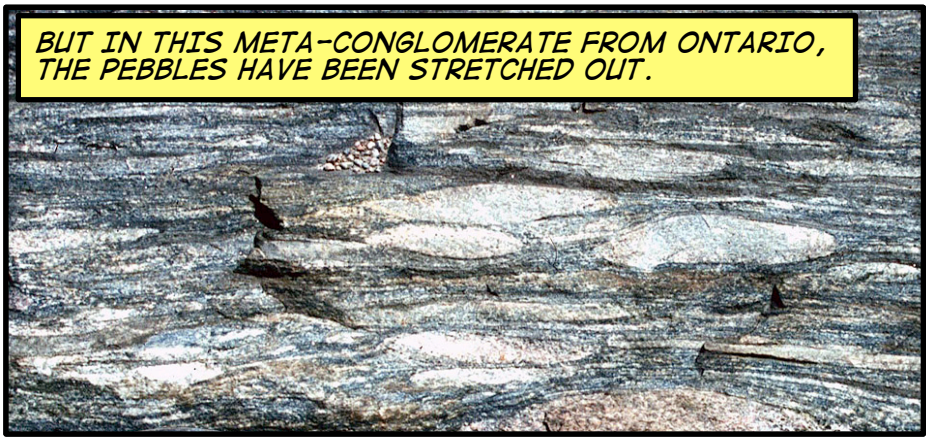
MAKES US REALIZE THAT THE VERY FABRIC OF THE ROCK HAS CHANGED.



THESE CHANGES IN THE ROCK MATERIALS ARE CALLED "METAMORPHISM", AND METAMORPHIC ROCKS ALWAYS ORIGINATE FROM A PREEXISTING ROCK. IN FACT, THE TERM "METAMORPHISM" MEANS "CHANGE."

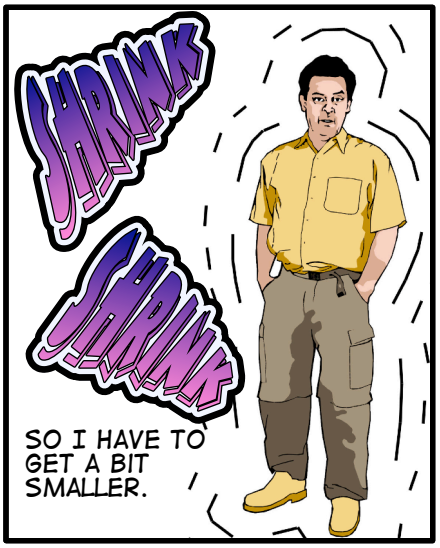
METAMORPHISM CAN CHANGE THE MINERALS THEMSELVES, THE ROCK "FABRIC" (OR TEXTURE), THE DENSITY OF THE ROCK, AND EVEN THE SHAPES OF THE GRAINS OR FOSSILS WITHIN THE ROCK! FOR EXAMPLE ...

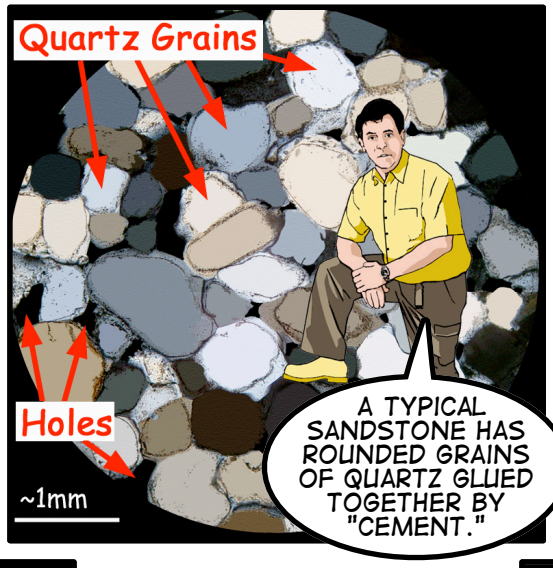
THIS CONGLOMERATE FROM NORTHERN WISCONSIN HAS NICE ROUNDED PEBBLES (SOMETIMES CALLED CLASTS) IN IT.



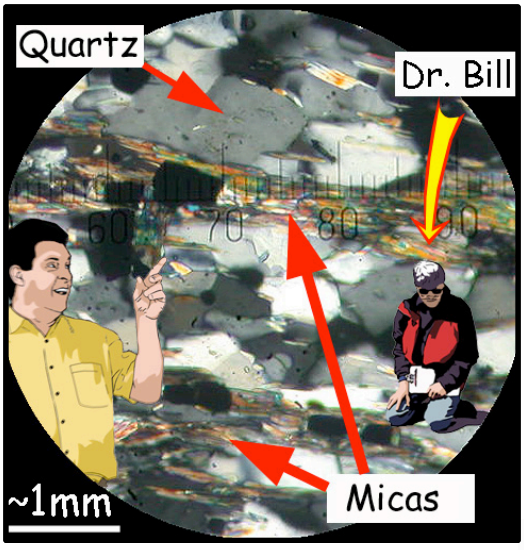
NOT SURPRISINGLY, THE META-CONGLOMERATE IS MUCH DENSER. THERE ARE NO CAVITIES BETWEEN THE PEBBLES BECAUSE THEY'VE BEEN CRUSHED TOGETHER. THIS CRUSHING CONTRIBUTES TO CHANGES IN THE MINERALS THEMSELVES.

LET'S TAKE THE SIMPLE SEDIMENTARY ROCK, SANDSTONE, AND GO INSIDE IT TO SEE WHAT HAPPENS AS IT IS METAMORPHICALLY CHANGED ...



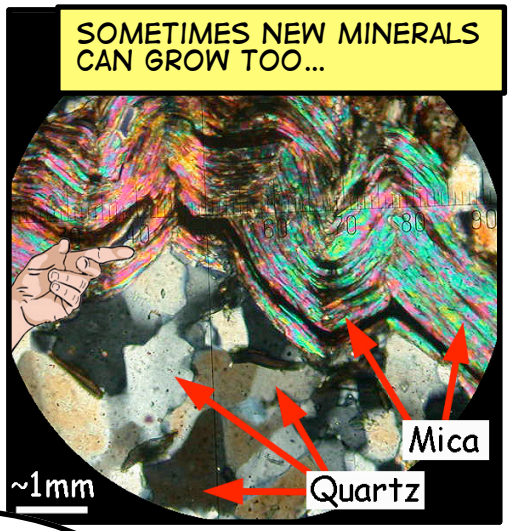


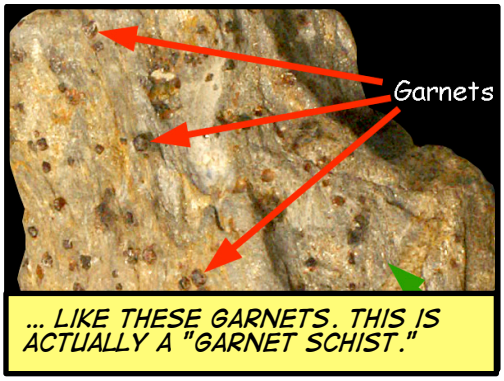
SOME SANDSTONES ARE CONTAMINATED WITH CLAY, WHICH CHANGES TO BECOME MICA DURING METAMORPHISM. THE MICAS GROW IN, OR ARE ROTATED TO, A SPECIFIC ORIENTATION: PERPENDICULAR TO COMPRESSION. NOTICE IN THE NEXT PICTURE THAT THE QUARTZ GRAINS HAVE NOT CHANGED SHAPE LIKE THE CONGLOMERATE PEBBLES. THEY'RE TOO STIFF TO DO THAT. THE MICAS, THOUGH, ARE ALL ALIGNED, CAUSING A "FOLIATION" IN THE ROCK.

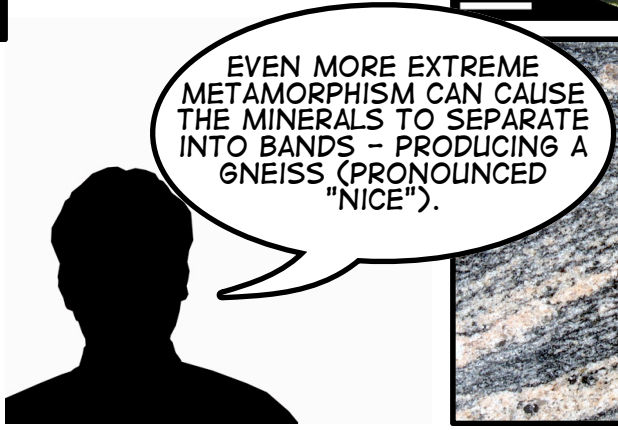


SO THE MICAS GROW FROM THE CLAYS THAT WERE PART OF THE ORIGINAL SEDIMENTARY ROCK. THE QUARTZ CRYSTALS DON'T CHANGE NATURE OR SHAPE, BUT THEY DO GET PACKED CLOSER TOGETHER AND GROW LARGER. AND IF THE COMPRESSION CHANGES DIRECTION, THEN THE MICAS BECOME FOLDED, BUT NOT THE QUARTZ (IT'S TOO STIFF).

SOMETIMES NEW MINERALS CAN GROW TOO...



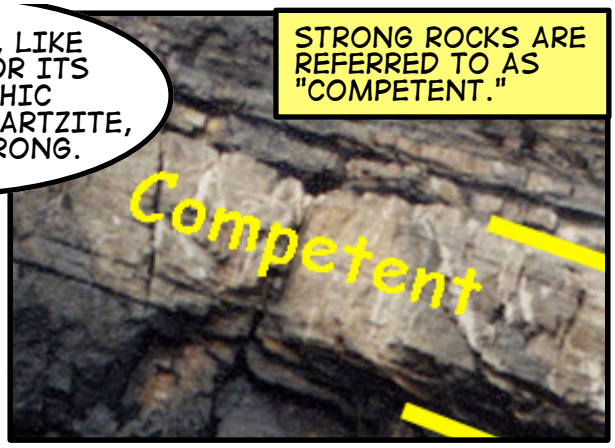




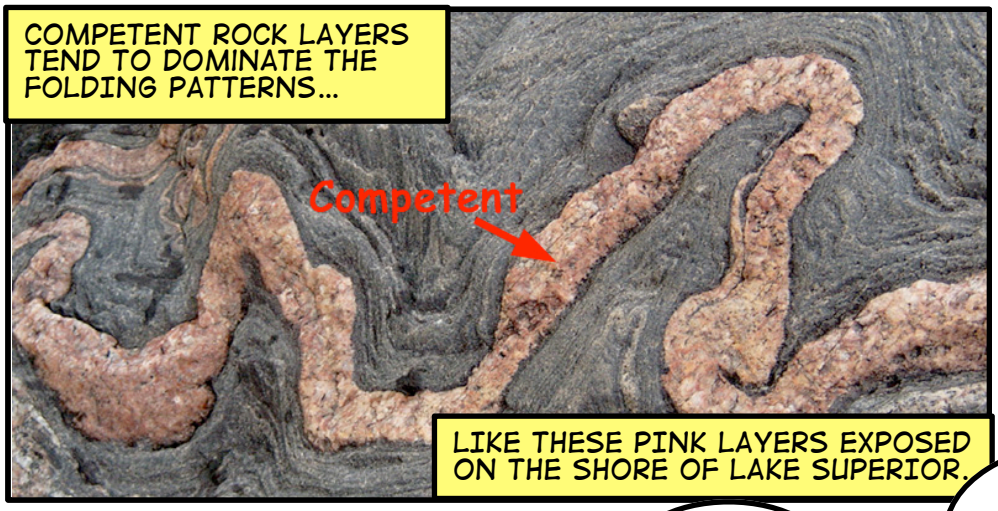
HIGH TEMPERATURES AND PRESSURES, TYPICAL OF DEEPER IN THE CRUST, ARE NEEDED TO PRODUCE SCHIST OR GNEISS. UNDER THESE CONDITIONS THE ROCKS CAN BEHAVE IN INTERESTING WAYS, DEPENDING ON WHAT THEY ARE MADE OF.

SOME ROCKS, LIKE SANDSTONE OR ITS METAMORPHIC EQUIVALENT, QUARTZITE, ARE VERY STRONG.

STRONG ROCKS ARE REFERRED TO AS "COMPETENT."



COMPETENT ROCK LAYERS TEND TO DOMINATE THE FOLDING PATTERNS...



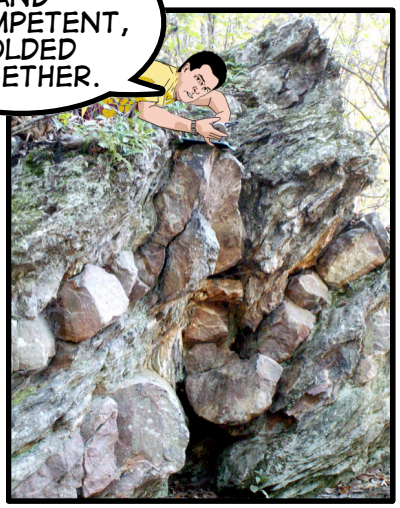
LIKE THESE PINK LAYERS EXPOSED ON THE SHORE OF LAKE SUPERIOR.

COMPETENT LAYERS, THAT ARE STRONG AND STIFF, FOLD THE WAY THEY HAVE TO AND ALL THE OTHER, SO CALLED, INCOMPETENT LAYERS FIT IN TO ACCOMMODATE THAT PATTERN. CLASSIC EXAMPLES OF THESE WEAK INCOMPETENT ROCKS ARE COAL, SHALE AND EVAPORITE

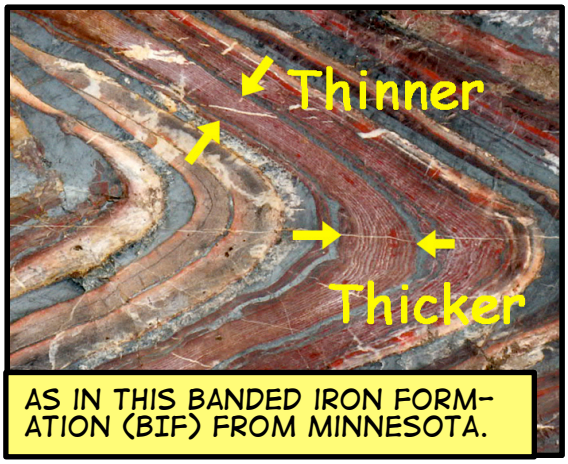
SUCH AS THIS.

HERE WE HAVE BOTH

COMPETENT AND INCOMPETENT, FOLDED TOGETHER.



SO THE COMPETENT LAYERS FORM WELL-DEFINED FOLDS, AND THE INCOMPETENT LAYERS FLOW AROUND THEM TO "FILL IN THE GAPS." SOMETIMES THIS CAN LEAD TO A DIFFERENCE IN LAYER THICKNESS BETWEEN THE HINGE OF THE FOLD AN THE LIMBS...

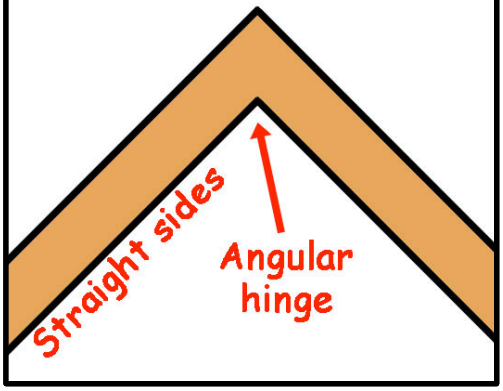


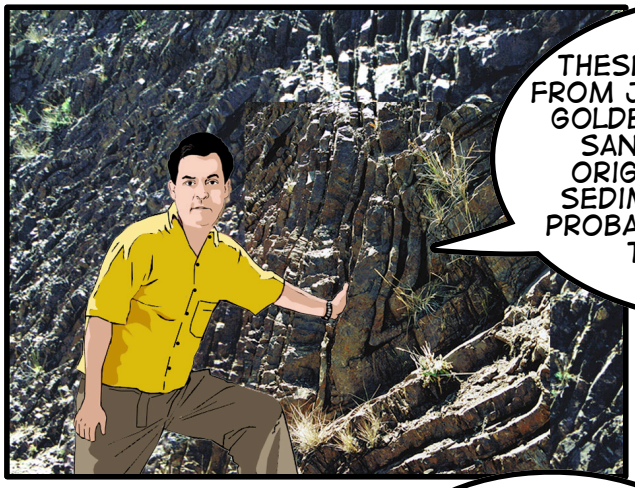
AS IN THIS BANDED IRON FORMATION (BIF) FROM MINNESOTA.

BUT OBVIOUSLY COMPETENCE ISN'T THE ENTIRE STORY. THE CONDITIONS OF FOLDING ALSO INFLUENCE WHAT TYPE OF FOLDS FORM. AT HIGH TEMPERATURES WE MIGHT EXPECT LAYERS TO BEND EASILY, BUT AT LOW TEMPERATURES THEY MORE EASILY BREAK.

ACTUALLY, HIGH IN THE CRUST WITH LOWER TEMPERATURES AND PRESSURES WE OFTEN SEE FOLDS THAT HAVE A VERY SHARP BEND IN THEM - CALLED CHEVRON FOLDS ...

LIKE THIS.





THESE CHEVRON FOLDS FROM JUST NORTH OF THE GOLDEN GATE BRIDGE IN SAN FRANCISCO ARE ORIGINALLY DEEP SEA SEDIMENTS, BUT WERE PROBABLY FORMED NEAR THE SURFACE.

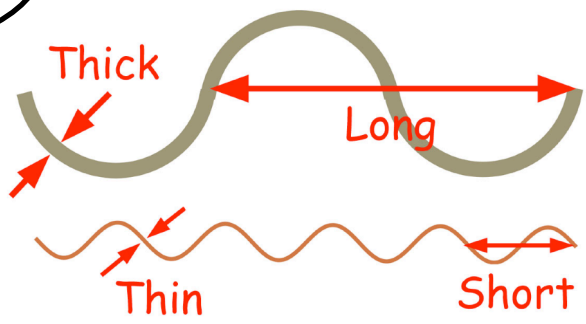
IF THE INCOMPETENT ROCK DOES FLOW BETWEEN THE COMPETENT LAYERS ...

THEN WE SEE MORE SMOOTHLY CURVED FOLDS, AS WE SAW IN THE MINNESOTAN BIF. THESE ARE TYPICAL OF THE HIGH TEMPERATURES AND PRESSURES WHICH PROBABLY EXIST MUCH DEEPER IN THE CRUST- AND SO PROBABLY REPRESENT THE DEEP INTERIOR OF A MOUNTAIN CHAIN.

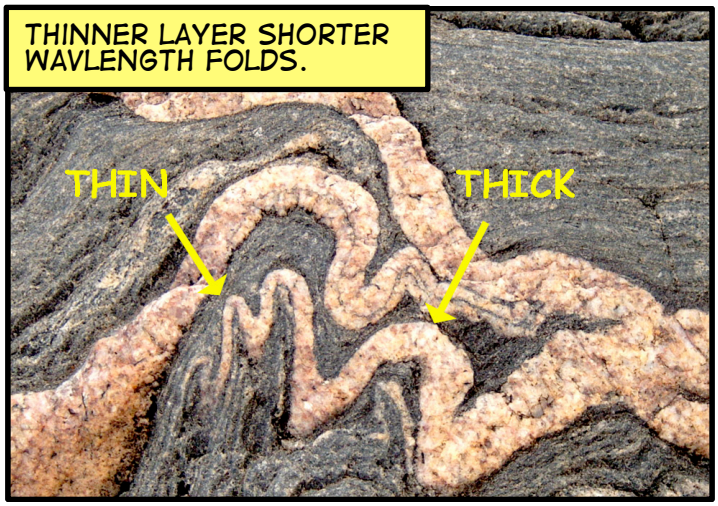
BUT ITS THE COMPETENT BEDS THAT DOMINATE THE FOLDING STYLE.

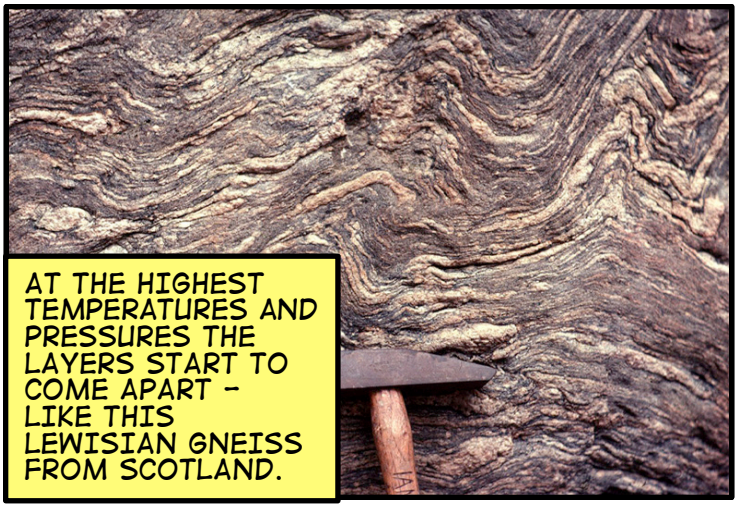
ACTUALLY FOLD WAVELENGTH DEPENDS ON HOW THICK THE LAYERS ARE TOO.

THICKER LAYERS FORMING LONGER WAVELENGTH FOLDS AND ...



THINNER LAYER SHORTER WAVLENGTH FOLDS.





AT THE HIGHEST TEMPERATURES AND PRESSURES THE LAYERS START TO COME APART - LIKE THIS LEWISIAN GNEISS FROM SCOTLAND.