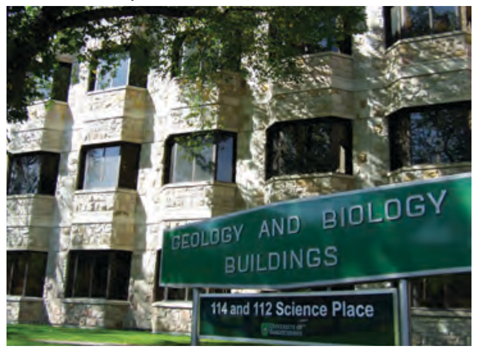
What is Geology?

Geology is the study of the Earth, from the highest mountains to the core of the planet, and has traditionally been divided into physical geology and historical geology. Physical geology concentrates on the materials that compose the Earth and the natural processes that take place within the earth to shape its surface. Historical geology focuses on Earth history from its fiery beginnings to the present. Geology also explores the interactions between the lithosphere (the solid Earth), the atmosphere, the biosphere (plants, animals and soil) and the hydrosphere (oceans, rivers, lakes and groundwater), both today and over the course of time. Geoscientists study phenomena such as plate tectonics, earthquakes, volcanoes, glaciers, mountains, shorelines, minerals and gems and global climate change. Related areas of study include biology, chemistry, mathematics, physical geography and physics.

A Stepping Stone...

A degree in Geology, Geophysics, or Environmental Geoscience provides an excellent academic background for students who like both science and nature, are curious about the Earth's origin and history and who care about its future. University programs will be of particular interest to those who wish to pursue advanced study in specific areas of geoscience such as structural geology, mineral deposit geology, petroleum geology, geophysics, geochemistry, mineralogy, petrology, paleontology, ichnology, palaeobotany, hydrogeology, sedimentology, stratigraphy and seismology. A Master's or PhD degree can be a significant advantage in terms of career opportunities. Graduates from the Department of Geological Sciences at the U of S have been highly successful in graduate programs all across North America, and industry careers all over the world.



Career Opportunities

Whether you want to work in an office, a laboratory, in some of the Earth's most exotic places, or maybe a combination of all three, there are a wide variety of professional opportunities open to geological sciences graduates. Many pursue professional careers with energy and mining companies, governments, research institutes, consulting firms and universities. Modern geologists are involved in the analysis of natural hazards, in the prevention and control of environmental problems and in the safe development of mineral and energy resources. They investigate the geological past through the study of fossils and rocks and use the knowledge of the Earth's history to evaluate phenomena such as global climate change.

What is the purpose of this map?

The Geologic Boulder Map of Campus has been created as an educational outreach tool by the Department of Geological Sciences at the University of Saskatchewan. The map was designed to give individuals who may be interested in Geology an introduction to the subject and to provide information on the origin of some of the boulders and building stones on campus. The map highlights interesting rocks around campus, many of which you may pass by every day. It is our goal to put you in the shoes of a geologist and to view rocks through his or her eyes.

How is the map arranged and how can you use it?

On the opposite side of this brochure is a map of campus showing the location of boulders and their rock type, along with more detailed information pertaining to specific sites or boulders. A description of what you will see is provided, as well as what a geologist may envision to be the rock's history. Three 'Geo-walks' have also been suggested, in which you can follow a specific route and encounter examples that describe changes within a main theme. These themes are Igneous Rocks, Metamorphic Rocks and Unique Boulders.

Igneous Geo-walk

The root of "igneous" is from the Latin word *ignis* meaning fire. Outlined in red, this path takes you across campus looking at these ancient "fire" rocks, some of which may have been formed at great depths in the Earth's crust. Created by the cooling of magma or lava, they can widely vary in both grain size and mineral composition. This walk stops at examples showing this variety to help you understand what the change in circumstances will do to the appearance of the rock. Geologists use the relative proportions of the minerals, quartz, plagioclase feldspar and alkali feldspar to classify and name these types of rocks. We also use different names, depending on whether these magmas cooled slowly to form crystals visible to the naked eye, as an intrusive rock, or cooled rapidly to form crystals that can only be seen with a microscope, as an extrusive rock. Many igneous rocks also have unique textures that develop as they cool, and can further distinguish different kinds of igneous rocks.

Metamorphic Geo-walk

Following the dark blue path shows you what it is like to withstand immense heat and incredibly high pressures. You can see different stages of the geological process called metamorphism and how varying heat and pressure will affect a rock. Geologists classify this rock type based on metamorphic textures and what the rock was previous to deformation, or its protolith. A gneiss, for example, is a general term for a banded metamorphic rock; however, if we know that it formed from a granitic protolith,we may further classify it as a granitic gneiss. If a specific mineral is abundant, we may add it to the name of the rock (e.g., hornblende gneiss). This process of classification is similar for the other metamorphic textures, including slates, schists and phyllites.

Unique Boulder Geo-walk

The light blue path does not follow a geologic trend. It shows you the unique specimens that add to the geological complexity found here at the University, making it such an interesting place. You will see all of the rock types, including points with multiple boulders of interest, boulders with unique textures or structures, and boulders to zoom in on and explain specific concepts not covered in other areas.

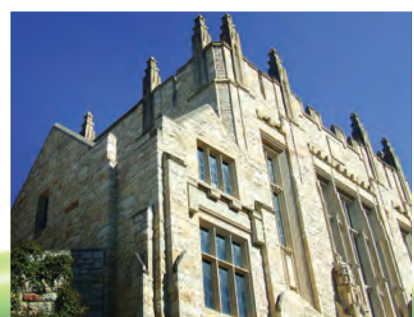
Boulder Information

Physical weathering breaks down rock into smaller chunks or separate crystals collectively called detritus. Any of these 'chunks' larger than 256 millimeters (mm) in diameter are called "boulders" by geologists. Because the term boulder refers to the size of a rock and not its origin, the boulders may be of Sedimentary, Igneous or Metamorphic origin.

Even though the boulders on campus may have called the University home for a long time, it is unlikely that the rocks originally formed nearby. Saskatchewan has had a very complex geological history, but some of the more recent geological materials were deposited during the last Ice Age. About 10,000 years ago, Saskatchewan was covered by an ice sheet, which transported all sorts of debris from northern Canada towards the south. As the ice sheet melted and receded, the material it was carrying was deposited. This material is called glacial till, and is usually poorly sorted, meaning that it is possible to find large boulders mixed with anything from clay to pebbles. The boulders transported by and deposited by ice sheets are called "erratics". All across campus the boulders we see were most likely transported to the vicinity of the campus by this process, and thus originally came from areas to the north, such as the Precambrian Shield. Most of the boulders were then moved to their present location during the construction of the campus buildings, walkways, parking lots and landscaping.

Tyndall Stone and other Building material

As you walk around campus it is easy to see that there are not only a large number of boulders, but that rock is integrated into our buildings as well. In 1910, construction started on the College Building. They used a limestone (or Greystone), which was quarried just north of campus. This Greystone became a recognizable campus signature until the local supply of limestone was exhausted. The University then turned to Tyndall Stone and Fieldstone. Essentially Greystone, Fieldstone and Tyndall Stone are all the same, dolomitized limestone that comes from the same rock unit, which is exposed from northern Saskatchewan down to north of Winnipeg. Tyndall Stone is quarried from the Ordovician Red River Forma-tion in the vicinity of Tyndall, Manitoba. This rock is famous for its cream colour and pervasive coloured mottling, which may have been caused by the burrowing of marine creatures when the limestone was deposited. It also contains numerous fossils including gastropods, brachiopods, receptaculita and rugose coral. The best example of these are in the Geology Building where the stone was hand-picked for its fossil display.



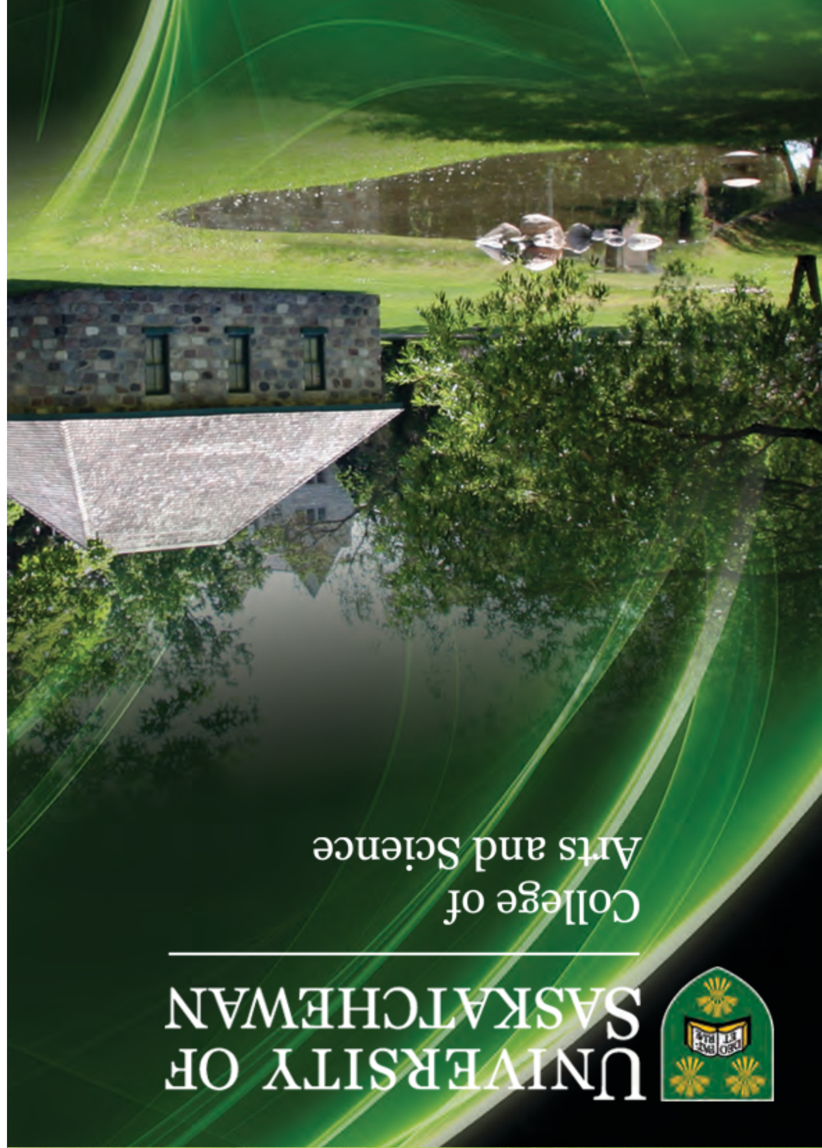
Granite is another common building stone used on campus. When companies sell granite, they do not use the same classification system as geologists. Granite is sold in many different colours and mineral compositions that a geologist would name differently. For example, the granite used as a structural base for the College Building has a composition closer to a granodiorite than a granite. Similarly, the granite used for the stairs at the entrance to the Thorvaldson Building is also granodioritic in composition.

Glossary of Geological Terms

Alkali feldspar: a variously coloured (often pink to red), common rock-forming mineral of the feldspar group, rich in the alkali elements potassium and sodium. One of the main constituents of granite and rhyolite, but it also occurs in metamorphic and sedimentary rocks.
Aphanitic: an igneous rock containing grains that are so small as to be barely visible to the naked eye.
Basalt: a dark-coloured, fine-grained mafic volcanic rock.
Biotite: an important rock-forming mineral of the mica group. It is generally black and flaky in form, and can be found primarily in igneous and metamorphic rocks.
Deformation: a change in the shape, position or orientation of a material by bending, breaking or flowing.
Dolostone: a carbonate sedimentary rock composed of the mineral dolomite.
Dynamic recrystallization: a process where the nucleation and growth of new grains occurs during deformation rather than afterwards as part of a separate heat treatment.
Feldspar: the most widespread of any rock-forming mineral group, feldspars make up 60% of the Earth's crust and are common in most rock types. Major elements in feldspars may vary between calcium, potassium and sodium. When a feldspar is compositionally between potassium and sodium we call it an alkali feldspar, and if it is between sodium and calcium we call it a plagioclase feldspar.
Felsic: used to describe igneous rocks that are composed mostly of light-coloured minerals, such as quartz, feldspars, feldspathoids or muscovite. These minerals tend to be rich in sodium, potassium and aluminum.
Foliation: Layering formed as a consequence of the alignment of mineral grains or of compositional banding in a metamorphic rock.
Gneiss: a rock formed by regional metamorphism in which bands of light-coloured granular minerals alternate with bands of dark-coloured flaky minerals.
Granite: a light-coloured, coarse-grained plutonic rock dominated by feldspar and quartz, but often containing mica and amphibole.
Igneous rock: a rock that has solidified from hot molten material (magma or lava).
Mafic: used to describe igneous rocks that are composed mostly of dark-coloured minerals, such as pyroxene, amphibole, olivine or biotite. These minerals tend to be rich in magnesium, iron and calcium.
Magma: naturally occurring molten and mobile material, generated within the Earth and capable of intrusion or extrusion. When magma hardens, igneous rocks are formed. Magma that reaches and extrudes onto the Earth's surface is termed lava.
Matrix: term denoting the interstitial material lying between larger crystals, fragments or particles.
Metamorphic rock: any rock derived from pre-existing rocks by mineralogical, chemical and structural changes in response to changes in pressure and temperature. The process is referred to as metamorphism and the rock undergoing it has been metamorphosed.
Meta-: a prefix for rocks that have undergone metamorphism.
Mica: a group of common minerals, including muscovite (transparent) and biotite (brown to black), that can be easily split into elastic flaky plates.
Mineral: a naturally occurring inorganic element or compound having an orderly internal structure and characteristic chemical composition, crystal form and physical properties.
Mylonite: a streaky or banded rock, produced by intense ductile deformation during shearing.
Pegmatite: very coarse-grained igneous rock.
Phaneritic: an igneous rock containing components large enough to be seen with the unaided eye.
Phenocryst: a large crystal surrounded by a finer-grained matrix in an igneous rock.
Plagioclase feldspar: variously coloured (often white), common rock-forming mineral of the feldspar group, rich in calcium and sodium. One of the main constituents of granodiorite and gabbro, but it also occurs in many other igneous rocks, as well as metamorphic and sedimentary rocks.
Plutonic (Intrusive) rock: a medium- to coarse-grained igneous rock formed at considerable depth by crystallization of magma; synonymous with intrusive rock.
Porphyritic: the texture of an igneous rock in which larger crystals (phenocrysts) are set in a finer-grained groundmass.
Porphyroblasts: large mineral crystal in a metamorphic rock that has grown within the finer-grained groundmass.
Quartz: next to feldspar, the most common rock-forming mineral. It is transparent, harder than feldspar and widespread in igneous, metamorphic and sedimentary rocks.
Rhyolite: a light-coloured, fine-grained volcanic rock compositionally the same as granite.
Sedimentary rock: a rock resulting from the consolidation of loose sediment that has accumulated in layers. Sedimentary can be divided into Clastic, Chemical and Organic, depending on how they have formed.
Shearing stress: stress that slices rocks into parallel blocks that slide in opposite directions along their adjacent sides.
Texture: the general physical appearance or character of a rock.
Vein: a tabular deposit of minerals occupying a fracture, in which particles may grow away from the walls toward the middle.
Volcanic (Extrusive) rock: a fine-grained igneous rock formed when magma reaches Earth's surface and hardens (crystallizes); synonymous with extrusive rock.
Weathering: the processes that break up and corrode solid rock, eventually transforming it into sediments.
Xenolith: an inclusion of a pre-existing rock in an igneous rock. Often derived from country rock that has been invaded by an igneous mass.

Geologic Boulder Map of Campus

Revised by Cecily Smith, Donna Beneteau and Kevin Ansell (2022)
First edition written by Adam Larsen, Kevin Ansell and Tim Prokopiuk (2010)



UNIVERSITY OF SASKATCHEWAN
College of Arts and Science

Additional Resources

Useful other resources include the book *Saskatoon's Stone* by Kim Mysyk & Christine L. Kulyk, and outreach materials available at: https://sgshome.ca/outreach. The Saskatchewan Geological Society website includes *Geoscape Posters, a Geological Highway Map of Saskatchewan*, and *GeoExplore Saskatchewan*.

Acknowledgments

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1

The Geology building is partially constructed from fossil-containing dolomitic limestone, Tyndall Stone. Near the dinosaurs are examples of receptaculites, stromatoporoids, rugose and tabulate coral, gastropods, and cephalopods. Can you find them all? Look at the main floor displays of beautiful minerals, and check out the website of the Museum of Natural Sciences at: https://artsandscience.usask.ca/museumofnaturalsciences/

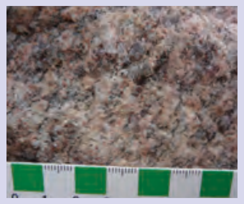
2

At first glance on the side of the boulder with the plaque there appears to be a layer with an obvious rust colour. This is a **weathering** product as it only occurs at the surface. Looking at the sides of the boulder reveals a planar texture, which geologists call a **foliation**. This is caused by deformation during **metamorphism** of the host rock, which was a Porphyritic Granodiorite. If we look closely, the foliation wraps around the large **alkali feldspar** crystals, suggesting that the crystals formed before pressure was applied to create the foliation. Another feature is the darker, **mafic**-rich **xenoliths**, which represent fragments of the surrounding rock that were incorporated into the **magma** before it crystallized.

3

A Meta-Tonalite cross-cut by a later **pegmatite vein**, as well as possible localized melt and trace amounts of garnet is an example of how complex rocks can be, revealing evidence of multiple processes at work. As a tonalite, it is composed of large amounts of **plagioclase feldspar** with over 20% **quartz** and less than 10% **alkali feldspar**. There is evidence of **deformation** through alignment of grains and some white blotches suggesting melting. The formation of garnet is also indicative of **metamorphic** processes. Ferromagnesian **minerals** can breakdown due to increases in temperature and pressure and recrystallize as garnet during **metamorphism**.

4



Metamorphism and **deformation** occur at varying degrees of intensity. Some rocks like this Meta-Granite were only mildly **deformed**, as is seen by the preferred orientation of the darker hornblende and **biotite** crystals. Even though the **metamorphism** and **deformation** were great enough to start creating **foliation** of these **mafic** minerals, it was not enough to create a visible change of the feldspars and quartz in the rock. However, it may be possible to see evidence within them if looked at under a microscope.

5

The most distinctive feature of this **igneous rock** is the large crystals of **alkali feldspar**, which, together with the smaller crystals, gives the rock **porphyritic texture**. **Quartz** also appears as a minor portion along with smaller amounts of the darker **minerals**: hornblende and biotite. The **porphyritic texture** forms when **magma**, rising through the Earth's crust, is cooled at different rates. The **feldspars** cooled slowly deeper in the crust, allowing the crystals to grow larger, while the other **minerals**, including other **feldspars**, formed as the **magma** cooled more quickly, resulting in smaller crystals that are still visible to the naked eye. Geologists would call this rock a Porphyritic Monzodiorite.

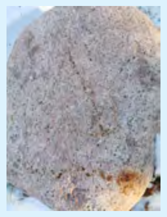
6

Largely composed of **mafic minerals**, a Gabbro will still contain **plagioclase feldspar**, but almost no **quartz** or **alkali feldspars**. This boulder gets its dark colour from high portions of **mafic minerals** including hornblende, pyroxenes and minor biotite. The **phaneritic texture** tells us that this is an **intrusive** rock and if compared to the smaller boulder beside it, we notice similar compositions but slightly different grain sizes. The small boulder would still be considered a gabbro, but it would have formed at a shallower depth within the Earth's crust compared to the rock that makes up the larger boulder. If the same **magma** rose to the surface rapidly, erupted at a volcano, such as Hawaii, then crystallized, the result would be a dark rock with microscopic crystals called a basalt.

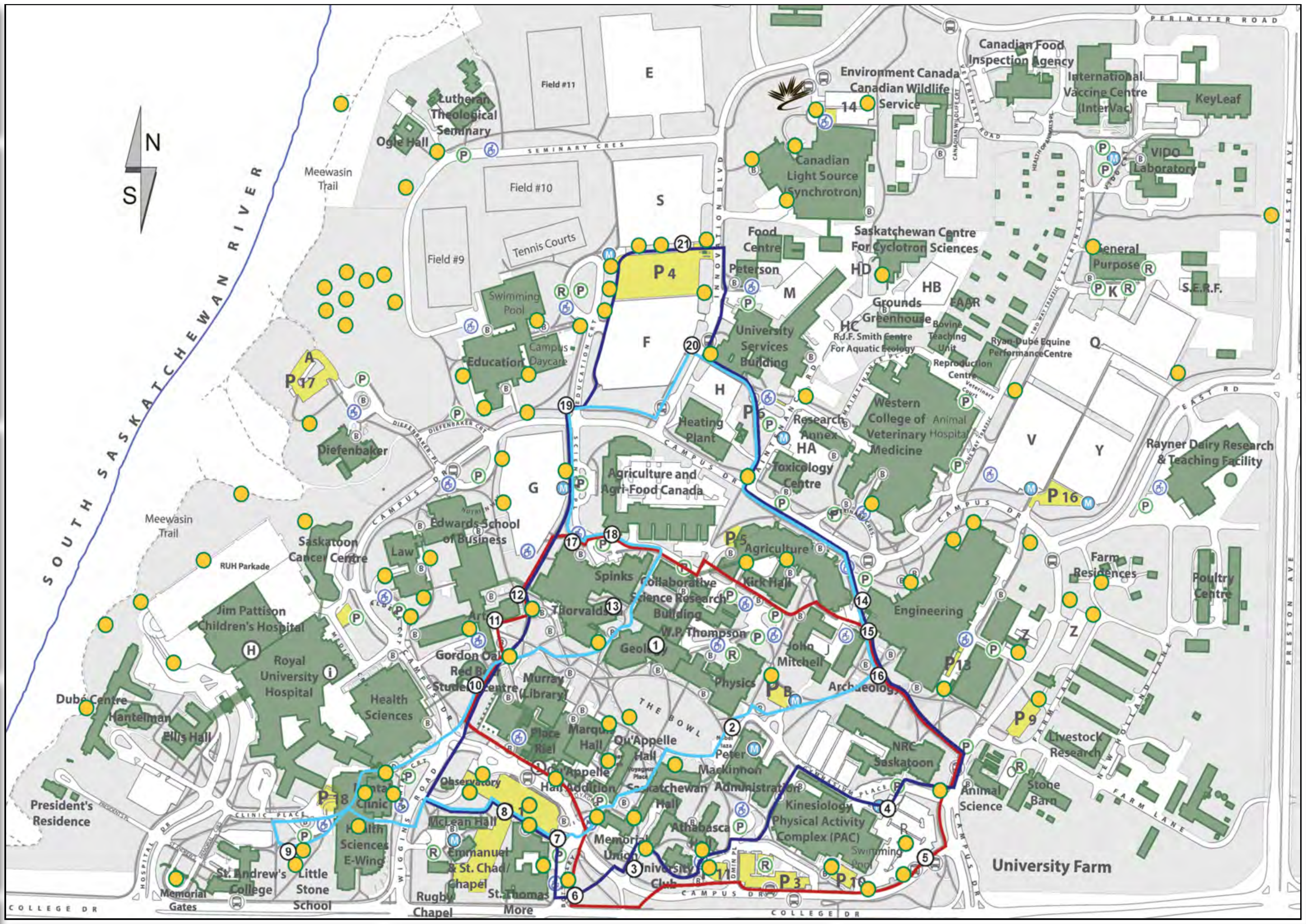
6

A rock may look very different from one side to the next and this boulder is no exception. From the top, you see a large **pegmatite**, but looking from the side you find that there is much more going on. The light bands are more **pegmatites**, similar to the large **pegmatite** on the top of the boulder, **intruded** into this **mafic**-rich rock. Intense **deformation** during **metamorphism** followed to cause changes in the rock. The **pegmatites** are mainly large **alkali feldspar** crystals and you can see large individual crystals in the small bands. Imagine these are original **feldspars** in the **pegmatite** that were broken, separated and stretched during **deformation**. If you look closely, you may see rims around these crystals created by recrystallization during the **metamorphic** event.

7



The three boulders at this location are all **igneous rocks**, and all are types of **granite**. The boulder nearest the sidewalk is a good example of a granite dominated by pink **alkali feldspar**, with small areas of white and grey **plagioclase feldspar**, and **quartz**. Dark minerals are rare, which is very different from the boulder of Gabbro at point 6. The difference between the boulders emphasizes that the **magmas** from which igneous rocks form can have very different chemical compositions, which is related to the types of rocks that melt to produce the magmas.



LEGEND

Buildings	Igneous
Buildings Under Construction	Metamorphic
Underground Walkway	Unique
① Highlight Boulders	Igneous Geo-walk
Areas with Boulders	Metamorphic Geo-walk
	Unique Geo-walk

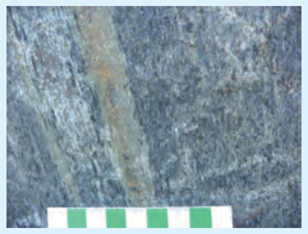
8

To understand this **metamorphic rock** it is essential to have an idea of what it was before being **deformed** and **metamorphosed**. This was previously a **sedimentary rock** called a Conglomerate. It consisted of individual clasts, or fragments of pre-existing rocks, within a finer-grained **matrix**. To get a good idea of what this looks like, imagine the sand, gravel and pebbles that this boulder lies on turned into a rock. **Deformation** later stretched and distorted the clasts, producing what is called a Meta-Conglomerate. This rock is quite dark in colour due to the high **mafic** content of the finer-grained **matrix**.

8

A gneiss is created by high-grade **metamorphic** processes acting on pre-existing rocks that were originally **igneous**, **sedimentary** or even other **metamorphic rocks**. The **minerals** are arranged in bands that may be poorly or well developed. This Granodioritic Gneiss is an example of the latter. The bands in this boulder are coarse grained and between more felsic lighter bands vary and **mafic** dark bands.

8



The **mafic** content within this gneiss is much higher than many other examples outlined in this brochure. The grain size is fairly small, making the identification of the different **minerals** difficult. The lighter areas contain **plagioclase feldspars**, the darker areas may have a variety of **minerals** including hornblende and pyroxenes, and the green patches may be chlorite. The larger hornblende crystals randomly distributed throughout the rock are **porphyroblasts**, which are crystals that grow during **metamorphism**. These are often confused with **phenocrysts**, which are crystals that grow from **magma**, and predate **metamorphism**. To create a Mafic Gneiss such as this would require high pressures and temperatures.

9

The "Little Stone School House", or Victoria School House, was originally built in 1887 by a local stone mason on the southwest corner of Broadway and 12th Street. Because of the construction of the larger Victoria School in 1909 on the same site, the one room school was no longer needed. It was proposed that that the historic building be relocated to the University. The schoolhouse was dismantled and rebuilt stone by stone at its present location. There are many interesting stones making up the walls of this school and each one is different from the next. The variety and quality of these rocks make it a great place to stop to see many different examples of rocks on campus, all at one location.

10

The design of the Gordon Oakes Red Bear Student Centre is rich with cultural significance. The exterior of the building is composed of Tyndall stone that adorns many other buildings on campus. The stone wraps around the building creating a symbolic blanket to protect the building's centre from the harsh Prairie winds. To find out what the symbols and features in the entire building represent, visit indigenous.usask.ca/about/about-gorbsc.php#TheBuildingandVirtualTour

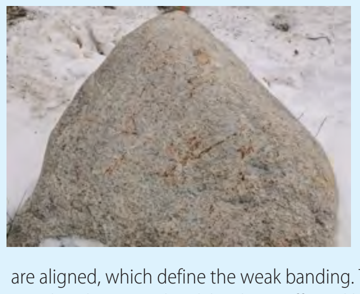
11

This boulder is an excellent example of a typical Pegmatitic Granite (usually just referred to as a **pegmatite**). Notice the large crystals of pink (**alkali**) and white (**plagioclase**) **feldspars**, transparent **quartz**, and the clusters of mica sheets. This particular mica is light in colour and is called muscovite. It differs from the darker variety, biotite, by the lack of iron and magnesium. One notable feature found in this rock is the intergrowth **texture** on the side (pointed out by the arrow). This is an intergrowth of **quartz** and **alkali feldspars** that creates a 'wormy' appearance termed graphic intergrowth, and occurs principally in **pegmatites**.

12

This boulder is an **igneous rock** called a Diorite. However, an interesting element of this rock is that it is cut by fractures, which are filled by a 'pistachio green'-coloured **mineral**. This colour is characteristic of the common silicate mineral called epidote. It is likely that the epidote formed from hot salty waters that filled the fracture after the diorite had completely crystallized, with the result being a **vein** of epidote.

13



The boulder is an example of a **metamorphic rock**. The original rock was a **granite**, with pink **alkali feldspar**, and light-coloured **plagioclase feldspar**, and **quartz**. Unlike some of the other examples of **gneiss**, the banding is not obvious. However, if you look carefully on some of the sides of the boulder you will see that the rare darker minerals are aligned, which define the weak banding. The presence of this banding does tell you that the original rock has been affected by metamorphism and **deformation.**

14

This is an interesting-looking rock with a complex history. When a **metamorphic rock** reaches extreme temperature conditions partial melting may occur and we refer to the resulting rock as a Migmatite. The lighter area, or leucosome, is dominated by **feldspar** and **quartz** and derived from the crystallization of the melt. The darker area, or melanosome, is rich in dark minerals such as **biotite** and hornblende. It is the solid portion of the rock left after some or all of the melt has been extracted. This is a great example of in situ melting as the melt has been separated from the solid but has remained at the site where it formed. The "intestine-like" folding that you can see is called Ptygmatic folding and generally represents the conditions where the folded material is either more viscous or stronger than the surrounding material.

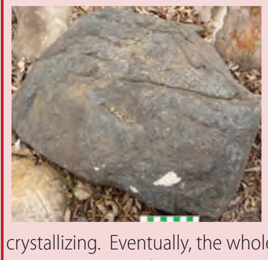
15

Granite is a common **igneous intrusive rock** in the continental crust. However, it can be quite variable in appearance depending on the relative proportion of **minerals** and their grain sizes and **textures**. This boulder is an ex-ample of a typical granite. It contains similar proportions of **plagioclase** and **alkali feldspars** with **quartz** being slightly more abundant. There are also small amounts of the darker **minerals**: biotite and hornblende.

16

Garnet is a well-known **mineral** commonly found in metamorphic rocks. In this rock we see red-purple garnet **porphyroblasts**, the term used for large **minerals** that grow within a rock as a result of high temperatures and pressures during **metamorphism**. The colour of the garnet will vary depending on its composition, although the colour shown by the garnets in this boulder is most common. The garnets grow as a result of the redistribution of elements within the rock that become available as pre-existing **minerals** react and breakdown during **metamorphism**.

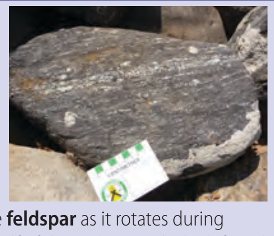
16



This is a unique boulder because it is one of the few boulders of **volcanic** origin found on campus. A geologist would call it a Porphyritic Basalt. It is an **extrusive igneous rock** having **plagioclase feldspar phenocrysts** within a fine-grained, **mafic matrix**. For a rock such as this to form, the **mafic magma** would need to be held in a **magma** chamber at a shallow depth within the Earth's crust. The conditions in this **magma** chamber would be right for **plagioclase feldspar** crystals to start crystallizing. Eventually, the whole **magma**, which contained **plagioclase** crystals, was erupted to the surface where it crystallized into a basalt, enclosing these previously formed **feldspars**.

16

Among this patch of boulders are a number of interesting rocks. One worth highlighting is called a **Mylonite**. It is a **metamorphic rock** produced during intense **deformation** by **dynamic recrystallization** and reduction in grain size of the **minerals**. The rock is one that you would find within a shear zone in the lower part of the crust. This rock contains a good example of a large **feldspar** grain, which has distinctive recrystallized 'wings' that records growth of **minerals** around the **feldspar** as it rotates during deformation. The direction of shearing moved the top half of the rock towards the left and the bottom half of the rock towards the right.



17

This wall is built entirely of fieldstone and greystone bricks. Notice that a large number of buildings use this rock and that each block varies in colouration. This is because each individual block has a slightly different chemical composition so each one weathers slightly differently.

18

This Granodiorite is equigranular, which means that all grains are approximately the same size. They are also visible to the naked eye, so we classify the **texture** of this rock as **phaneritic**. The **quartz** crystals are grey in colour and have a glassy appearance, which distinguish them from **plagioclase feldspar** crystals that are grey to white in colour and are cloudy. The alkali feldspar in this rock is not as prominent but shows up in pink, white and grey colours with a similar appearance to **plagioclase feldspar**. **Biotite** is distributed throughout this rock and occurs as brown- to dark brown-coloured flakes or clusters of flakes but is not the only dark **mineral** present. Also found throughout this rock but more abundant within the **xenolith**, we find hornblende, which are typically black in colour.

18

This Gneiss exhibits excellent layering, and you can also see the effect that **weathering** has on a rock. The appearance of the rusty, but lighter-coloured **weathered** surface is very different from the slightly darker fresh rock underneath. Often certain **textural** features of a rock are more obvious on **weathered** surfaces than fresh surfaces, which may be useful in interpreting the origin of the rock. However, it is important to recognize **weathering** products from the original "fresh" **minerals** when trying to classify rocks. Therefore, in some respects, **weathering** can help us understand the rock better, whereas in other examples it may make things more difficult.

19

Gneissic rocks may be generated by varying amounts of heat and pressure. In a case such as this, there has been such intense **deformation** of the **mafic** and **felsic** layers that it creates a rock called a "straight gneiss". It has been squeezed to such a degree that the original angular relationship between layers, such as resulting from folding, has been destroyed, and all the layers are now parallel to each other.

20

The boulder is a good example of a **metamorphic rock** called a **gneiss**, that has had a complicated geological history. The main rock is dominated by dark **mafic** minerals, and the lighter coloured minerals, which are mainly **feldspars**, often are shaped like an "eye". This is because the rock has two **foliations**, which are defined by the alignment of the dark minerals. Can you see them? They are oriented at about 60 degrees to each other, and show that the rock underwent two period of **deformation.** The rock is also intruded by the light-coloured **pegmatite**, which has then been folded. Geologists try to work out the order in which the various features of the rock formed to unravel the history of the rock.

20

As you approach this boulder, you will see the view shown in the photograph. It looks like a rock dominated by dark **mafic minerals** with some patches of felsic minerals, with pink **alkali feldspar** being the most common. Is your first impression, correct? If you look around the boulder, you will see that it is banded **metamorphic** rock, called a **gneiss**, but that it is actually dominated by light-coloured **feldspars** and **quartz**. The mafic minerals define narrow bands in the rock, and so you were looking down on one of these dark bands, which forms the top of the boulder. This boulder shows that you need to look at all sides to work out what type of rock it is, and how it may have formed.

21

This is a fine-grained, **mafic** Gneiss containing multiple thin veins. It is noteworthy because this is very similar to a different highlighted boulder, except that this one has been **metamorphosed**. If you can imagine a rock very similar to the **porphyritic** basalt seen at pt.16 being **metamorphosed** and **deformed**, then you may end up with this rock, which now has a gneissic **texture**. Could the small light-coloured grains be stretched and **deformed feldspar phenocrysts**? If you now examine the **veins**, you will see that some pass straight through the rock, whereas others are folded. This is evidence that suggests that **veining** occurred both before and after the **metamorphic** and **deformation** event.