Lithostratigraphy and Age of Jacobsville Formation around the Lake Superior Basin, U.S.A. and Canada

G-122010-1A

2010

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Publication Number:
G-122010-1A

Cover Photo taken by: Steven D.J. Baumann on 9-6-2010
Photo is of the *Jacobsville Sandstone* in the Root River,
Sault Ste. Marie, Ontario

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Abstract

A detailed reclassification of the *Jacobsville Formation* around the Lake Superior region is needed in order to better understand Precambrian fluvial deposits. A more detailed division will aid in the location of mineral resources and greatly increase our understanding of a pre-snowball Earth environment. We propose dividing the *Jacobsville* into four members based on the work of previous authors. The streams that deposited the *Jacobsville Formation* left us with another problem. Since there are no fossils or known igneous intrusions into the formation, an age has been difficult to lock down. Determining the age of the *Jacobsville* will lead us to a better understanding of the formations above and below. Most geologists put its age somewhere between 1,100 to 540 million years ago. This is a huge gap! The age problem is complicated further by the lack of Mid-continental sedimentary deposits during this time. We have attempted to lock down an age using stratigraphic and event controls.

Photo taken by: Steven D.J. Baumann on 9-6-2010
Photo is of the fluvial sandstones of the *Jacobsville Formation,* at Root River Quarry, Sault Ste. Marie, Ontario. Notice the low angle cross bedding in the leached sandstone and the dark hematite rich laminations along bedding planes. One foot long hammer for scale.

Introduction

The *Jacobsville Formation* has held human interest for centuries. It was named in 1907 by Lane and Seaman after the Village of Jacobsville , which is located at the mouth of the Portage River on the Keweenaw Peninsula. The village was founded by John . H. Jacobson (Born: 1847, Died: 1934). In a round about way, he lived to see a geologic formation named after him. It is beautiful red and pale yellow, hard, mostly a quartz to subarkose sandstone, that has been used for building in the areas of Lake Superior to include the Upper Peninsula and Ontario and buildings as far south as Chicago. For being so instrumental in the construction industry, it is not well understood. It has been interpreted to be a deposit of **fluvial** origin, based on the cross bedding and lake deposits that it contains. Although the formation has been known to contain much iron, very little mineral exploration has occurred.

Not only is the **stratigraphy** within and mineral potential not well understood, the age of the formation has been elusive as well. In Canada the formation is generally considered **Cambrian**. In the United States, it is generally considered very late **Precambrian**. There is about a 560 million year discrepancy in accepted ages for the *Jacobsville*. This is understandable because there are generally not many deposits on the Mid-continent from 1,100 to 540 million years age. The problem is further compounded by the fact that it is not a marine deposit. This means we cannot assess an age based on paleo-current direction. Another side affect of being a formation deposited on land is that there are no **fossils** to date. There are no known igneous intrusions that cut through the *Jacobsville* that could also be used to assign an absolute minimum age.

Purpose

The purpose of this paper is to address the problems illustrated above. A redefinition of the *Jacobsville* in order to recognize **members** within the **formation** and an attempt to assign a reasonable age based on internal structure and stratigraphy.

Method

The method used to study and define internal lithologies in the *Jacobsville* are based on many decades of previous work of many authors (see references). These studies are based on both field and lab data.

The method used to date the formation is more of an academic problem. Using different criteria including lithology, hardness, color, mineral content, depositional origin, internal structure, and surrounding stratigraphy an attempt to find out when it was not deposited was more reliable than trying to guess an age. By ruling out depositional timeframes it became easier to identify spans of time when the *Jacobsville* could have been deposited.

Figure 1: Shows the complex cross beds present in the Jacobsville Formation.

Canadian $2 piece for scale.

Photo taken: 9-6-10. At the Root River Quarry in Sault Ste. Marie, Ontario

Stratigraphic Redefinition of the Jacobsville Formation

Outcrops of the *Jacobsville* are extensive throughout the Lake Superior region (see Attachment A1). Most outcrops occur in the Upper Peninsula but there are other outcrops in Ontario and Wisconsin. Lithologically the *Jacobsville* is pretty unique resembling only one other formation. It is similar to the older basal member of the *Freda Formation* of the *Oronto Group* except it contains much less shale and internal conglomerates. It also shares a heavy mineral assemblage with the *Orienta Formation* of the basal *Bayfield Group* as noted by Tyler in 1940.

The *Jacobsville* is one of the thickest **clastic** deposits in the area. In a drill hole conducted in 1982, the formation was 2861 feet thick near the northwest edge of its outcrop area (see Attachment A1). It this area the *Jacobsville* becomes deep basin fill along the Keweenaw **Fault** . Typically it is less than 1100 feet in thickness.

Baumann (2010) suggested that the *Jacobsville* be given group level status and the lake deposits be separated from the stream deposits and given formational status. Upon further reflection, this suggestion was abandoned. The *Jacobsville* has been firmly established as a formation and changing its rank to group may cause confusion.

Thomaston Member:
According to Hamblin and others, there are four distinct **lithologies** within the *Jacobsville*. There is a mostly basal sandy lithic conglomerate that contains clasts of **BIF**, vein quartz, volcanics (mostly greenstones), and metamorphic rocks. These deposits are believed to be alluvial fan deposits from where highlands suddenly meet a flat plain. A modern day example of this is Death Valley, where massive "fan" shaped deposits are common along the base of high hills and cliffs. There are minor conglomerates within the lower 1/3 of the *Jacobsville*. Since their extent is not known, they will not be addressed here as distinct lithological units but may exist as tongues that can be named in the future. This basal conglomerate can be as much as 350 feet thick, but in outcrop, it is generally no more than 16 feet thick. Due to the lateral and vertical extent of this basal member we propose that it be given formal status as the "*Thomaston Member*" named after Thomaston, Michigan (see Attachment A2 and A4) about 1 mile south of where it outcrops near Jackson Creek along the northeast corner of Section 28 and the southeast corner of Section 21, Township 48 North, Range 45 West. At this locality it is less than 2000 feet south of the east-west trending span along the Keweenaw Fault.

Root River Member:
Above the *Thomaston Member* lies the thickest and most continuous member of the formation. This second member is mostly of fluvial origin and was deposited by braided streams onto a flat sandy plain. This member is highly cross bedded (see Figure 2) and grades from a subarkose at its base to a nearly pure medium grained rounded **quartz arenite** with feldspar matrix. Feldspar content increases higher up in the member. This member is extremely hard, almost a meta-sandstone. This member is also a deep red to purple in color and often mottled a very pale yellow (see Figure 3). The red is caused by iron which can constitute up to 30% of a sample but, like the feldspar, is generally less than 5%. The red color is primary. It was deposited when the sandstone was. The pale mottling is caused by leaching, most like from groundwater movement. The fact that this member constitutes the overwhelming bulk of the formation warrants lithological formality. This unit is herein named the "*Root River Member*" named for outcrops along the Root River Sandstone Quarry just north of the town of Sault Ste. Marie, Ontario. GPS coordinates are at 46.5697°N by 84.3180°W at an elevation of about 750 to 770 feet above MSL.

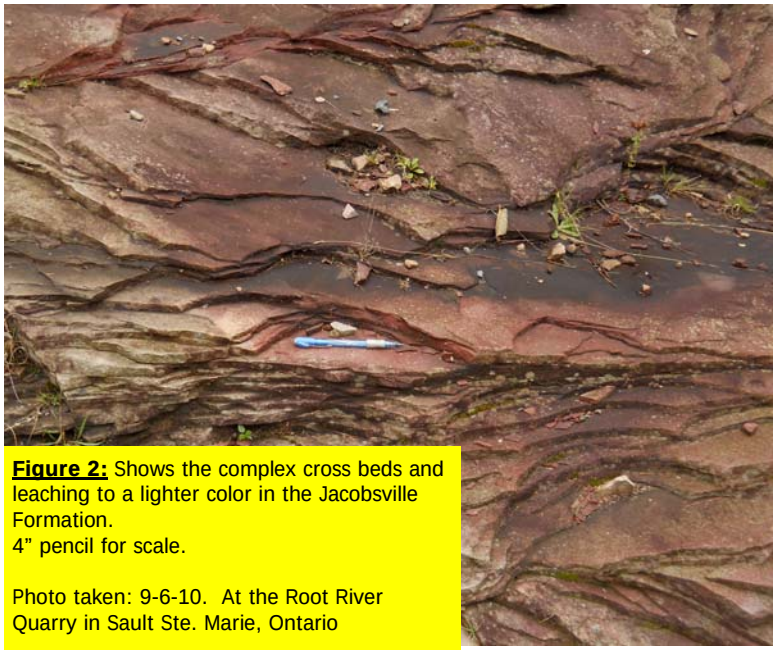


Figure 2: Shows the complex cross beds and leaching to a lighter color in the Jacobsville Formation.
4" pencil for scale.

Photo taken: 9-6-10. At the Root River Quarry in Sault Ste. Marie, Ontario

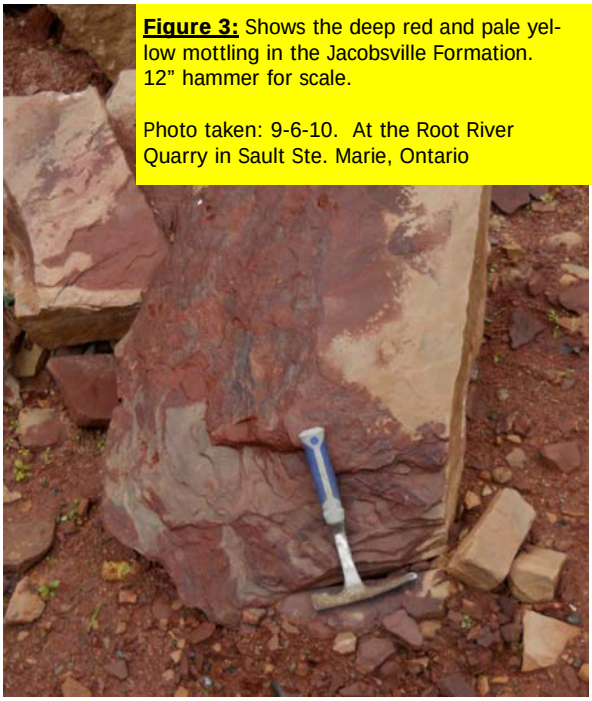


Figure 3: Shows the deep red and pale yellow mottling in the Jacobsville Formation.
12" hammer for scale.

Photo taken: 9-6-10. At the Root River Quarry in Sault Ste. Marie, Ontario

Victoria Falls Member:
The next member is represented by thick sandstones similar to the *Root River Member*. The main difference is depositional origin. Within the *Root River Member* are flat massive beds (up to nine feet thick) of relatively iron free fine to medium grained quartz arenites that contain oscillating ripple marks typical of **lacustrine** deposition. This member is up to 600 feet thick at its type section and represents a thick succession of shallow calm water lake deposits. This member is named herein as the "*Victoria Falls Member*" named after Victoria Falls, Michigan in Ontonagon County.

Heyden Member:
The final member also intertongues with the *Root River Member* and to a lesser degree the *Victoria Falls Member*. Like the *Victoria Falls Member* the "*Heyden Member*" is a lake deposit. It represents a muddy stagnant, deeper lacustrine environment (See Figure 4). This member is often referred to in older literature as the "red siltstone **facies**". The *Heyden Member* shares its type section with the *Root River Member*. Here the *Heyden* is represented by about five feet of blood red, fine sandy siltstone, often with dark gray (hematite) blotches. It is above 770 feet MSL and does not leach lighter as does the underlying *Root River Member*. It is often laminated with low angle cross laminations (see Figure 5) and occasionally interbedded with red sandstone. In Sault Ste. Marie, Michigan, near Lake Superior, and just southeast of the International Bridge, 30 feet of *Heyden* has been drilled into without reaching the bottom. It is possible that the member thickens to the south. It is named for the small town of Heyden located several miles north of the type section.

Figure 4: Stockpile of the Heyden Member. It is usually discarded since it has no known economic purpose.

Canadian $2 piece for scale (bottom center right).

Photo taken: 9-6-10. At the Root River Quarry in Sault Ste. Marie, Ontario

Figure 5: Shows the red Heyden Member overlying the Victoria Falls Member.

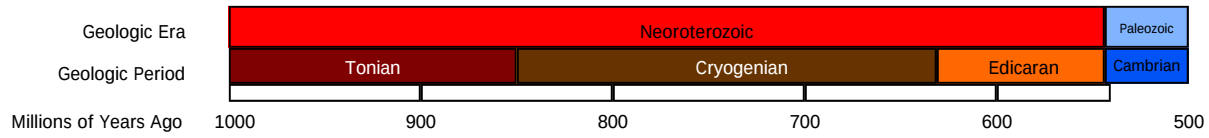
12" hammer for scale.

Photo taken: 9-6-10. At the Root River Quarry in Sault Ste. Marie, Ontario

Age of the Jacobsville Formation

The Age of the *Jacobsville* has been somewhat problematic. The only thing that is universally agreed on is that it was deposited sometime between 1,100 and 540 million years ago. Most American authors believe it is Late Precambrian (Neoproterozoic). Canadian authors tend to favor a Cambrian age. Americans favor the Precambrian age mostly because it fills the area of the Lake Superior Rift. In Canada, there is no strong structural control to suggest an age. Assigning an age is also complicated by the fact that the *Jacobsville* contains no fossils, is a **terrestrial** deposit, no **paleo-magnetic** data can be obtained, and no known igneous intrusions run through it to obtain a minimum age. The only definites are that it is younger than the *Oronto Group* and older than the Cambrian *Munising Formation*, as it is bounded by unconformities on top of the *Oronto* and below the *Munising*. Knowing that, we can at least establish a general timeline in order to assess a more definite age. The youngest *Oronto* strata is about 1,000 million years old and the oldest member of the *Munising Formation* is about 540 million years old. Knowing this we can set up a chart (Figure 6) and begin eliminating impossibilities from this point.

Figure 6: Basic Time Constraints for Jacobsville Deposition

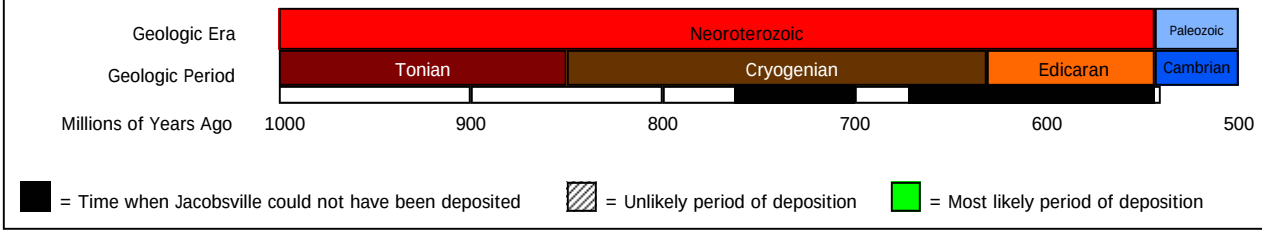


Glacial Time Constraints:

Once we establish a basic timeframe we can start to block out spans of time. In order to begin eliminating timeframes, it would help to know how long it took to deposit the *Jacobsville*. Fluvial sediments are generally deposited at a faster rate than marine sediments. In an actively subsiding basin they can do it very quickly. From other modern deposits we can assume a depositional time span from about eight to 50 million years. However, a more realistic time span is 20 to 30 million years. To err on the side of caution, 30 million years will be assumed. The *Jacobsville* contains rounded quarts grains, which take time to form. Depositional span of 20 million years is even less likely since there are stable lake deposits at different horizons within the *Jacobsville*. Fluvial lakes can last almost a million years, so this makes 30 million years (or more) the most likely time span for deposition.

What can we eliminate? We can start by eliminating the **Snowball Earth Events** and glacial periods during the Neoproterozoic. We can do this because the *Jacobsville* contains no glacial deposits. That basically eliminates the entire Edicaran (670 to 542 million years ago) almost the entire middle of the Cryogenian (760 to 700 million years ago). We can now block these two spans of time from our chart (see Figure 7).

Figure 7: Glacial Time Constraints for Jacobsville Deposition



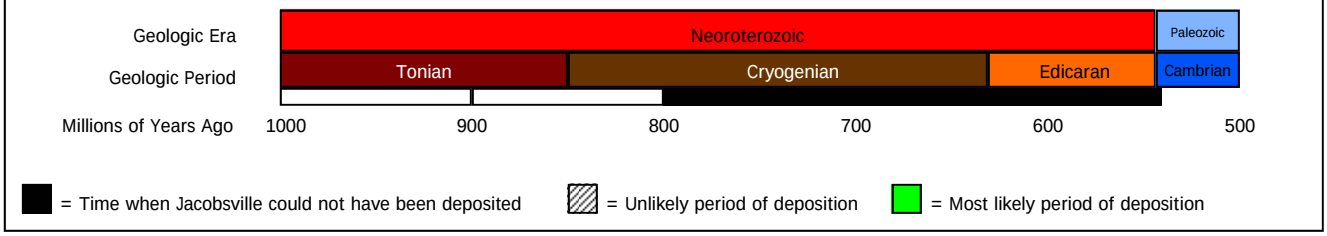
Cambrian Time Constraints:

We can rule out the Cambrian Period for a couple of reasons. First, there just isn't enough time at the beginning of the Cambrian to have deposited the *Jacobsville*. There is only about two million years from the beginning of the Cambrian to the beginning of the **Sauk Sea** advancement over the Mid-continent with the deposition of the *Munising*. The *Munising* is definitely at the very end of the Cambrian, based on Ordovician conodonts found at the very top (Miller, 2006) and is probably equivalent to the *Jordan Formation* in Wisconsin and Illinois. The *Munising* has two members. A basal pink sandy and shaley conglomerate called the *Chapel Rock Member* overlies the *Jacobsville* at Miners Castle in Michigan. An angular unconformity separates the two. The *Chapel Rock* is separated from the above pale colored sands of the *Miners Castle Member* by an unconformity (Bornhorst, 1999). Based on cross bedding, the *Chapel Rock* is indicated to have a sediment source from the northwest. The cross beds indicate a depositional source to the east as where the source for the *Jacobsville* was mainly from the south. The *Miners Castle* is most likely a fluvial-lacustrine to tidal flat deposit. As The *Chapel Rock* is marine deposits where the sea filled embayments along a jagged and very irregular shoreline (Hamblin, 1958).

The angular unconformity between the *Chapel Rock* and the *Jacobsville* and between the *Chapel Rock* and *Munising*, along with the different **sedimentary source** of both the *Miners Castle* and *Chapel Rock* are a very strong indication that the *Jacobsville* is significantly older than the *Munising Formation*. So how much time separates the two formations? A Cambrian age can be ruled out based on a lack of time for deposition and the relationships with the above *Munising*. We can also rule out the 700 to 670 million years ago during the Cryogenian. That 30 million year time span isn't long enough to allow for the angular unconformity to develop above the *Jacobsville*. More than 30 million years would be needed to erode older strata, deposit the thick *Jacobsville*, then deform it, and allow for further erosion to take place.

Neoproterozoic Time Constraints:
Most of the Cryogenian can be eliminated as well. Macro-life evolved around 800 million years ago. The fact that the *Munising*, which formed in a similar environment (at least in part), contains many fossils but the *Jacobsville* does not, is a strong indication that macro life had not yet evolved during the deposition of the *Jacobsville*. So we can further block out the 800 to 760 million year timeframe (see Figure 8).

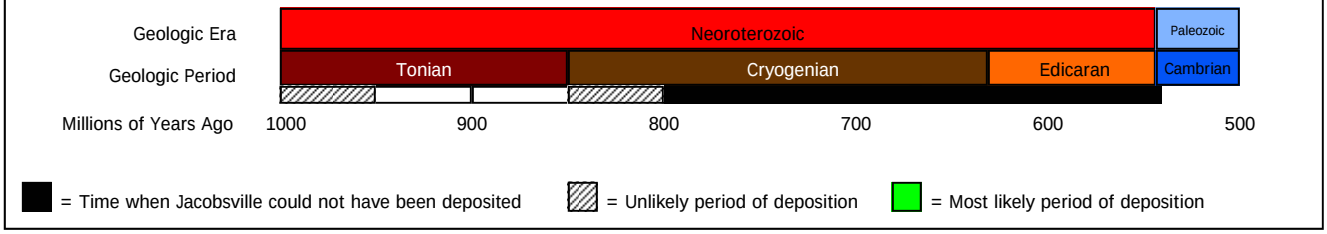
Figure 8: Cambrian and Cryogenian Time Constraints for Jacobsville Deposition



From this point on, restricting the age of the *Jacobsville* becomes more problematic. There is a 200 million year time span left that cannot be ruled out for certain. The *Bayfield Group* **unconformably** overlies the *Oronto Group* in Wisconsin. The *Bayfield* is pretty much known to be between 1,000 and 950 million years old. This is known because the Mid-continental Rifting in the area occurred near 1,110 million years ago and continued for 10 to 16 million years (Brandes, 2008). We know that the *Oronto* and *Bayfield Groups* filled this rift after it formed. Dickas, in 1986, went as far to state that the *Jacobsville* is equivalent to the entire *Bayfield Group*. Arguably, the *Jacobsville* does somewhat resemble the uppermost of the three *Bayfield Formations*, the *Chequamegon Sandstone*, which is believed to have been deposited in a similar environment between 950 and 975 million years ago. However, the *Jacobsville* does not lithologically resemble the lower two formations of the *Devils Island* and *Orienta Sandstones*. The *Jacobsvill*e is also nowhere near as thick as the *Bayfield Group*, which has a maximum thickness of 6,950 feet. This doesn't absolutely rule out a full *Bayfield* equivalent. It does restrict it to the uppermost Bayfield, at best. Plus the long term, continuous, stable environment of the *Jacobsville* suggests a slower filling and covering over a much larger area than the *Oronto* and *Bayfield Groups*.

On this basis, we can block out a time span of 1,000 to 950 million years ago with modest certainty but not definitely. Since the *Jacobsville* is partially a basin fill, we cannot rule much more time between 950 and 850 million years ago (see Figure 9). Based on the fact that during the Tonian and Early Cryogenian, the Mid-continent rift was already a failed rift, we can tentatively exclude at least the Early Cryogenian from 850 to 800 million years ago.

Figure 9: Early Tonian Time Constraints for Jacobsville Deposition



Final Time Constraints:
We are left with a 100 million year time span that allows for the depositional time frame of the *Jacobsville*. This is more than enough time to erode the older rocks, deposit the *Jacobsville*, bury and lithify it, tilt it in places, erode it in places, then deposit Cambrian sediments. Even if the *Jacobsville* took 50 million years to deposit, this large window still can't be reduced at this point.

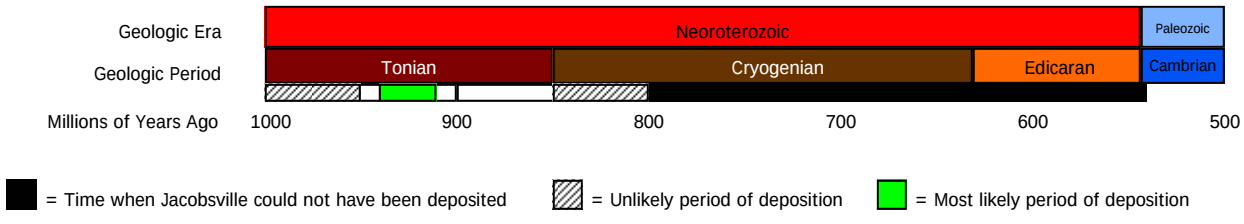
There are a couple more gauges we can use to decide on an age. One is the **lithification** of the *Jacobsville*. The sandstone in the *Jacobsville* is cemented very well with silica cement and it is almost a meta-sandstone. The shale parts are argillites at best. Assuming that this very low grade of metamorphism is present throughout, suggests that the *Jacobsville* was significantly buried before eroded and softer Cambrian sandstones were deposited. It is possible that the hardness of the *Jacobsville* can be attributed to groundwater movement over millions of years. This is unlikely since the *Jacobsville* has essentially zero percent carbonates in it. Groundwater would have leached through Cambrian carbonates via groundwater transport down into the *Jacobsville*, as it has done in the *Munising*, if this were the case.

The primary red color indicates an increase in atmospheric oxygen(O_2). O_2 content of the atmosphere is largely unknown between 1,800 and 750 million years ago. Much of the red color has been leached out over millions of years, so the original iron content isn't known. The deep red color suggests, although not definitely, an age closer to 950 million years based on colors of the *Freda* and *Chequamegon Sandstones* and the lack of red in later sediments.

One more obscure gauge is the Slate Islands Impact Crater in Ontario. Most workers (Dressler, Sharpton, 1995-1996) place the impact at 800 to 500 million years ago. However, brecciated clasts have reviled ages as old as 1,240 million years and **K-Ar dating** as young as 282 million years (Sharpton, 1999). The *Jacobsville* is present and brecciated at the impact site. Assuming an older age of the impact is correct, this would put the *Jacobsville* deposition around 900 million years ago. Until the crater can be dated accurately, its use in locking down an age for the *Jacobsville* should be taken lightly.

We are left with this 100 million year gap in time. Based on the color and weak metamorphism of the *Jacobsville* it would appear that we can assign an age between 950 and 900 million years ago. We will take a rough median of about 940 to 910 million years ago. This allows for a "buffer" at the 950 million year mark without bringing it too close to 950 million years. Until more data is compiled this age determination is about as good as it gets, although it can be anywhere within our left over 100 million year window (see Figure 10).

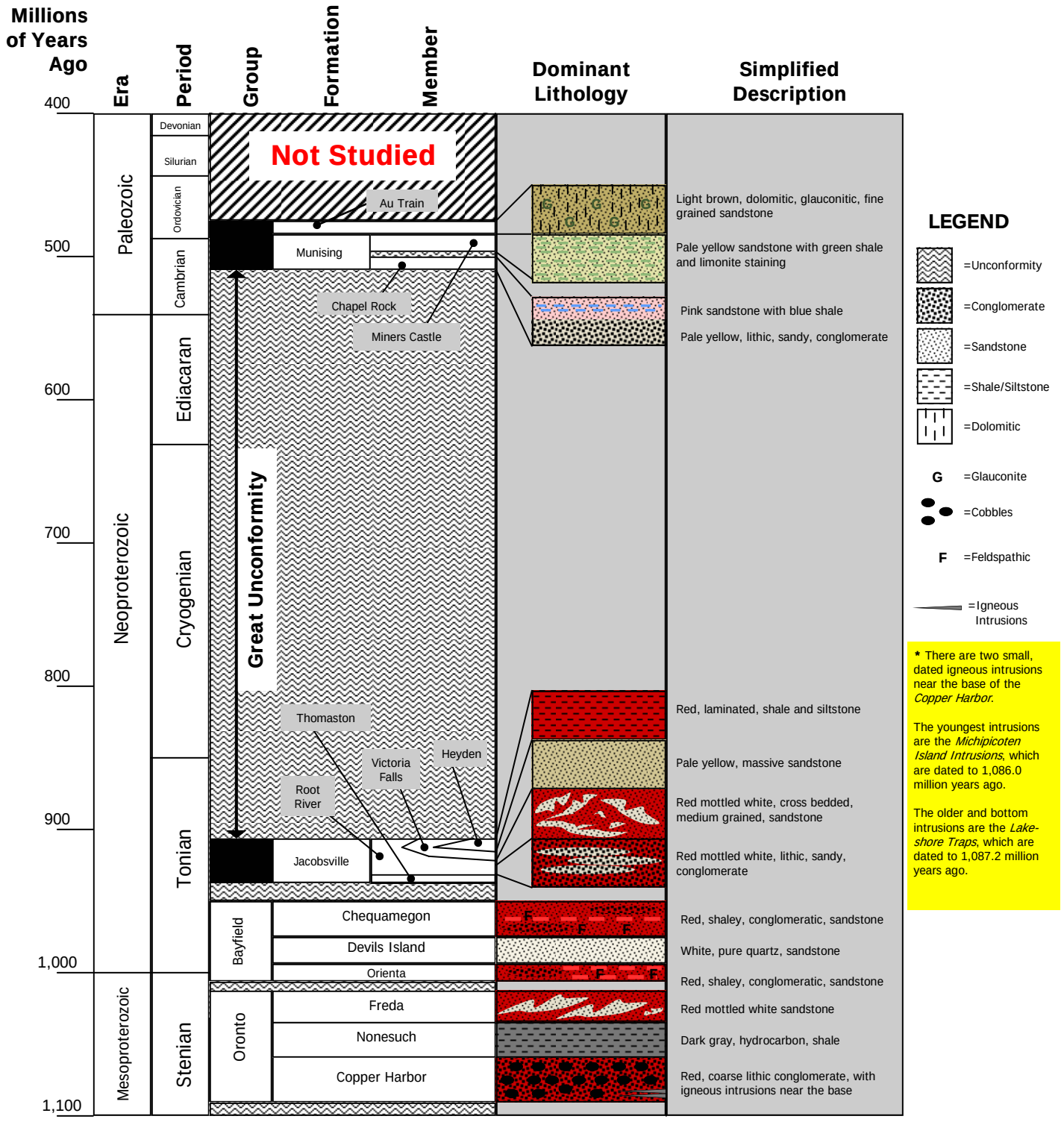
Figure 10: Final Time Constraints for Jacobsville Deposition



Conclusions

Redefining the *Jacobsville* aids us in a deeper understanding of how this understudied formation influenced the geology and mineral resources of Michigan and Ontario. The framework created will allow for the future naming of **tongues** and **lenses** in the future that can be identified as potential water and mineral sources. This along with attempting to lock down an age will also help us to understand the mineral potential of the *Jacobsville*. If we know the age and mineral viability of time-stratigraphic equivalents we can better narrow our search for the minerals that are most likely to be present within the *Jacobsville*. Figure 11 illustrates the lithology and timeframe of the *Jacobsville* and surrounding units as identified in this publication.

Figure 11: Time-Stratigraphic chart of the Jacobsville and surrounding formations of the Upper Peninsula, Michigan



Glossary:

BIF: Banded Iron Formations are sedimentary deposits (mostly Precambrian) that contain actual beds of iron along with carbonates, cherts, and clastics. Often the source of Tiger's Eye.

Cambrian: A worldwide geologic time period from 542 to 488 million years ago.

clastic: A term used to describe sediments that are not of carbonate or organic origin, usually sandstones and shales.

facies: An informal geologic unit within a formation or member.

fault: A break in the Earth's crust where movement has occurred along a planar surface.

fluvial: A terrestrial deposit of lake, steam, or wind origin.

formation: The fundamental, formal, geologic unit in stratigraphy.

fossils: Any evidence of past life.

K-Ar dating: Potassium–argon dating is a radiometric dating method used to determine age. It is based on measurement of the product of the radioactive decay of an isotope of potassium (K) into argon (Ar).

lacustrine: Deposits of lake origin.

lens(es): Formal stratigraphic units below a formation that are known to pinch in and out on all sides.

lithification: The process by which sediment is turned into rock.

lithology: Physical characteristics of a rock. i.e. color, bedding, grain size, composition

member: A formal division of the formation.

macro-life: Organisms larger than a single cell to exclude colonial single celled organisms.

paleo-magnetic: Locations of the magnetic poles before the beginning of human history.

Precambrian: A generic term referring to a span of time from the creation of the Earth (~4,567 million years ago) to the beginning of the Cambrian (542 million years ago).

quartz arenite: A sandstone comprised of $\geq$90% quartz.

Sauk Sea: The first of the six Phanerozoic (542 million years ago to the present) advancements of the ocean onto the continents. Beginning in middle Cambrian (521 million years ago) through the Early Ordovician (472 million years ago).

sediment: Unconsolidated Earth materials derived from an inorganic or organic source.

sedimentary source: The parent rock from which sediments are derived.

Snow Ball Earth Event: The theory that at numerous times during the Precambrian ice ages were so severe that the entire Earth was nearly frozen over.

stratigraphy: The study of rock units and how they relate to each other.

terrestrial: In geology it refers to sediments not of marine origin. i.e. river, lake, wind (eolian), glacial deposits

tongue(s): Formal stratigraphic units below a formation that are known to pinch out on one side.

unconformably (unconformity): A time span in Earth's history that is not preserved in the rock record.

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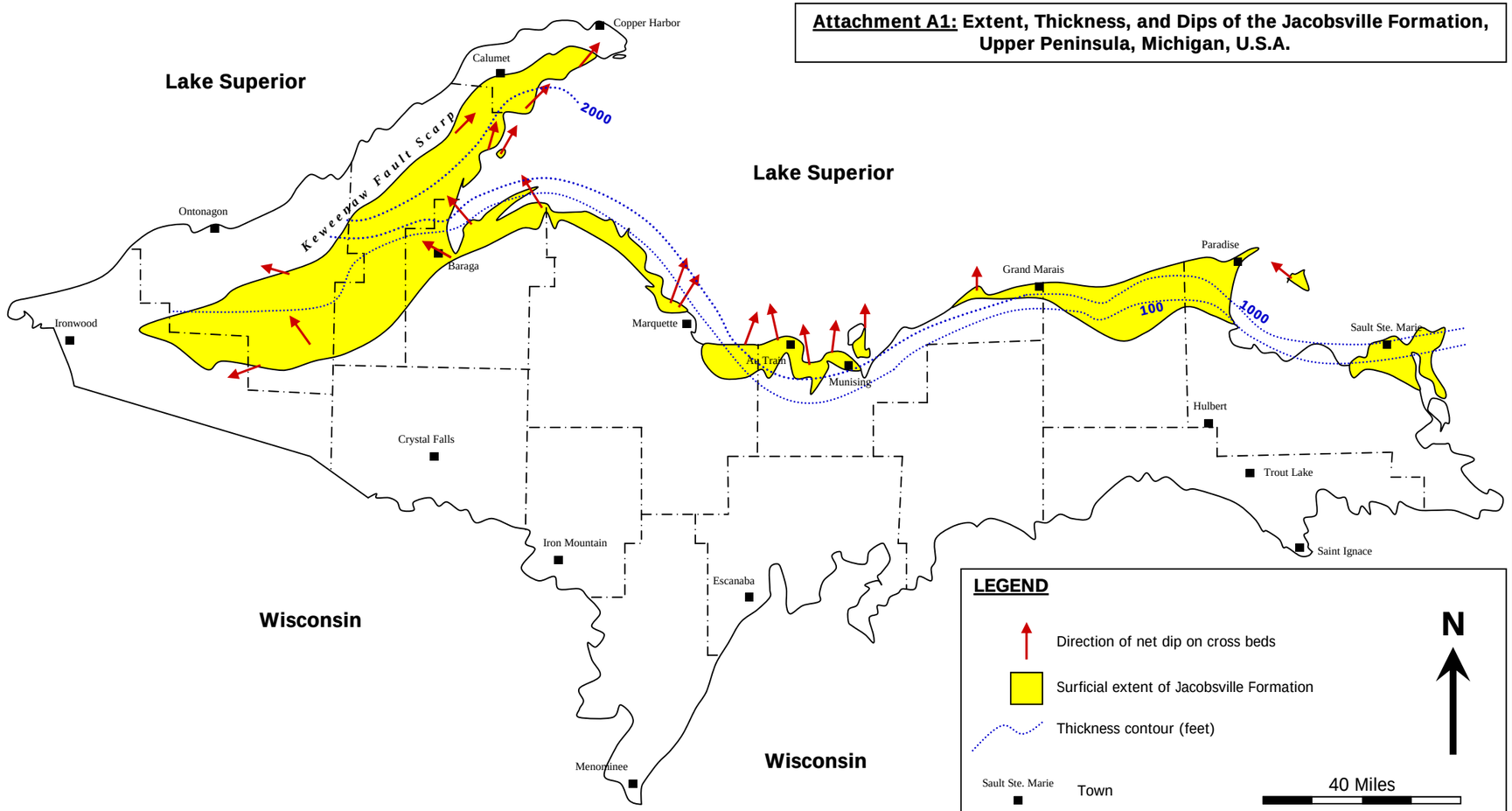
Special Thanks to: *Ed Kosiba*, Owner of the Root River Quarry, Sault Ste. Marie, Ontario

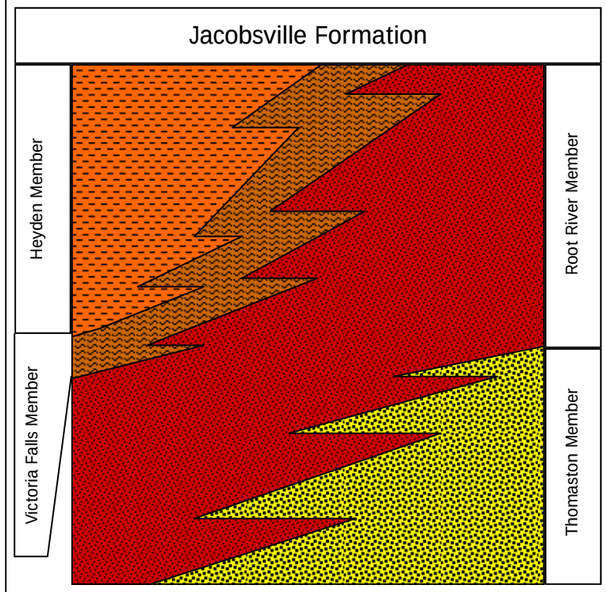
Attachment A: Analysis of the Jacobsville Formation

Attachment A1: Extent, Thickness, and Dips of the Jacobsville Formation, Upper Peninsula, Michigan, U.S.A.



Based on Hamblin, 1958

Attachment A2: New Nomenclature Suggestions for the Jacobsville Formation



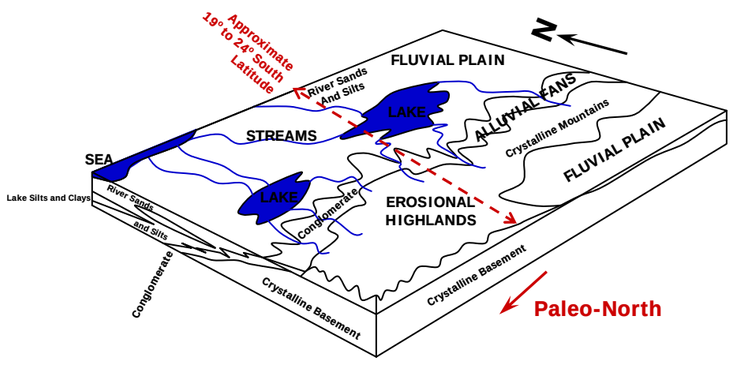
Heyden Member: Named for exposures in the Root River, several miles south of Heyden, Ontario where it is only several feet thick overlying the Root River Member. Also the designated type section which it shares with the Root River type section. The member was identified by Hamblin as the "red siltstone facies". Typically less than 30 feet thick, as it is in Sault Ste. Marie, Michigan, but can be as much as 100 feet thick. It is interpreted as muddy lake bottom sediments.

Vitoria Falls Member: Named for exposures at Victoria Falls, Michigan. Also the designated type section. The member exists in massive 9 foot beds within a 600 foot thick exposure. It is similar to lithology as the Root River Member except it generally not cross bedded and somewhat finer grained. It contains oscillating ripple marks conducive of a sandy lake bottom origin.

Root River Member: Named for exposures in a quarry along the Root River in Sault Ste. Marie, Ontario. It is a cross bedded, red mottled pale yellow, quartz arenite. It is well sorted consisting of mostly medium, rounded to well rounded sand grains. This member forms the vast bulk of the formation and can be as much as 2000 feet thick. Type area it is around 700 to 800 feet thick. It is fluvial in origin.

Thomaston Member: Named for exposures north of Thomaston, Michigan near Jackson Creek. This is also its type section. It is a sandy and poorly sorted conglomerate typical of alluvial fans. Although almost strictly a basal member, small tongues exist in the lower 1/3 of the Root River Member. The conglomerates are rarely more than 16 feet thick in outcrops but can be 350 feet in the subsurface.

Attachment A3: Environmental Setting of the Jacobsville Formation in the Upper Peninsula



Based on Hamblin, 1958

Attachment A4: Generic Cross Section of the Jacobsville Formation