



Light Pollution in Western North Dakota due to Regional Oil Development

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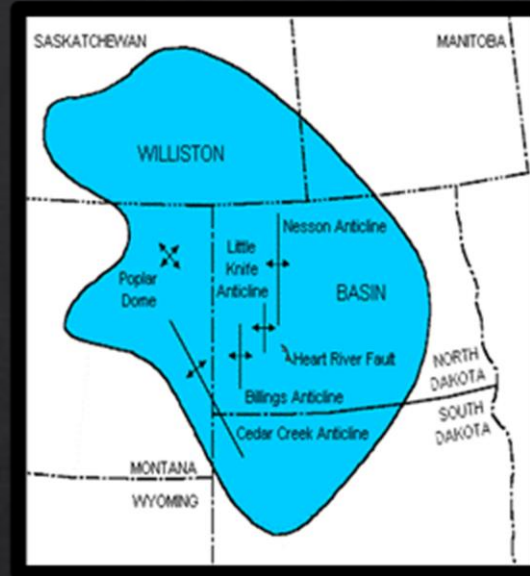
under the supervision of Dr. Corinne Brevik

Friday-April 7th, 2016



Geologic Setting of the Williston Basin

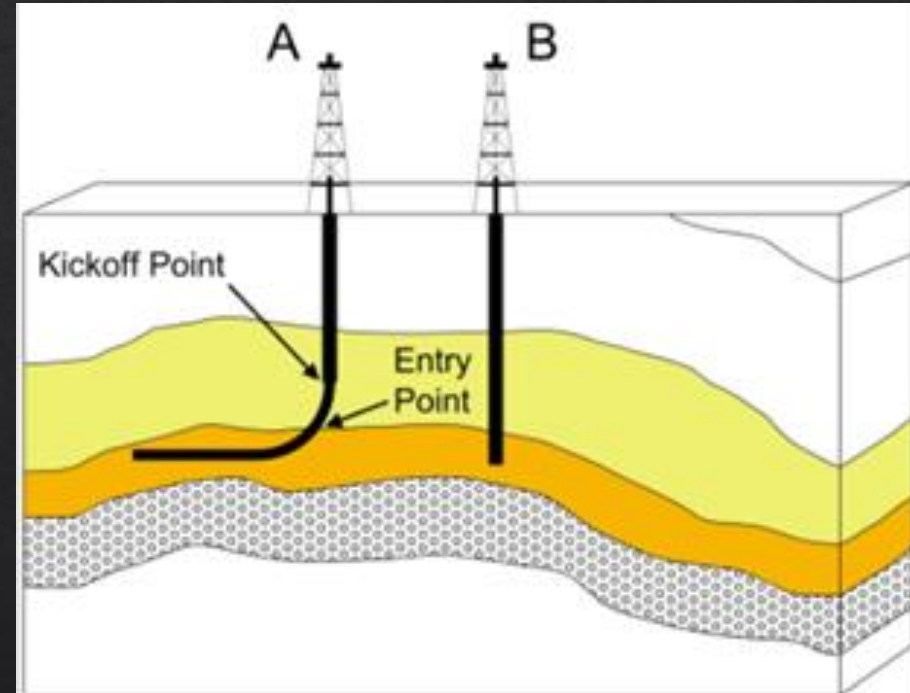
- ◆ Area of the Williston Basin
- ◆ Rock Record
- ◆ Bakken and Three Forks Formations
- ◆ Our oil and gas reserves were created by ancient marine microorganisms from around 542Mya to about 251Mya.



PRODUCING HORIZON LEGEND						
SOUTHERN WILLISTON BASIN						
ERA	PERIOD	EPOCH	MONTANA	CENTRAL BASIN	EASTERN FLANK	
CENOZOIC	QUATERNARY	RECENT	ALLUVIUM			
		PLEISTOCENE	GLACIAL DRIFT SOME GLACIOFLUVIAL DEPOSITS			
MESOZOIC	CRETACEOUS	UPPER	MONTANA GROUP	HELL CREEK FORMATION	FOX HILLS FORMATION	
			BEARPAW FM.	PIERRE SHALE FM.		
			CLAGGETT FM.			
		LOWER	DAKOTA GROUP	NIobrARA FORMATION	GREENHORN FORMATION	BELLE FOURCHE FORMATION
				MOWRY FORMATION	MUDDY (NEWCASTLE) FORMATION	SKULL CREEK FORMATION
				WYOMING KARA	FALL RIVER DAKOTA FM.	LAKOTA FORMATION
	JURASSIC	UPPER	MOHRISCH FM.	SUNNY FORMATION	BERGSON FORMATION	
		MIDDLE	NESSON FM.	DUNSMUIR SALT		
	PALEOZOIC	TRIASSIC	LOWER	SPEARFISH FORMATION		
			PERMIAN	MINNEKAHTA FM.	MINNEKAHTA FM.	MINNEKAHTA FM.
				OPECHE FM.	OPECHE FM.	OPECHE FM.
		MINNELUSA FM.		MINNELUSA FM.	MINNELUSA FM.	
PENNSYLVANIAN			AMSDEN FM.	AMSDEN FM.	AMSDEN FM.	
			TYLER FM.	TYLER FM.	TYLER FM.	
			HEATH FM.	OTTER FM.	OTTER FM.	
MISSISSIPPIAN		INDIAN GROUP		KIRBY FM.	KIRBY FM.	
				CHARLES FM.	POPLAR INTERVAL	
				BASE LAST SALT		
		MADISON GROUP UNDIFFERENTIATED		UNDIFFERENTIATED	BATTLERS INTERVAL	WISCONSIN ZONE
				UNDIFFERENTIATED	WISCONSIN ZONE	WISCONSIN ZONE
			UNDIFFERENTIATED	WISCONSIN ZONE	WISCONSIN ZONE	
			UNDIFFERENTIATED	WISCONSIN ZONE	WISCONSIN ZONE	
			UNDIFFERENTIATED	WISCONSIN ZONE	WISCONSIN ZONE	
			UNDIFFERENTIATED	WISCONSIN ZONE	WISCONSIN ZONE	
	LODGEPOLE FORMATION		LODGEPOLE FORMATION	LODGEPOLE FORMATION	LODGEPOLE FORMATION	
			LODGEPOLE FORMATION	LODGEPOLE FORMATION	LODGEPOLE FORMATION	
			LODGEPOLE FORMATION	LODGEPOLE FORMATION	LODGEPOLE FORMATION	
DEVONIAN	UPPER	BARRETT FM.	THREE FORKS FM.	THREE FORKS FM.		
		NIOSKI FM.	NIOSKI (BRUSSELE) FORMATION	NIOSKI (BRUSSELE) FORMATION		
		DUPERCIE FM.	DUPERCIE FM.	DUPERCIE FM.		
MIDDLE		PRAIRIE FM.	PRAIRIE FM.	WINDYBUSH FM.		
		PRAIRIE FM.	PRAIRIE FM.	WINDYBUSH FM.		
SILURIAN		INTERLAKE FORMATION	INTERLAKE FORMATION	INTERLAKE FORMATION		
		INTERLAKE FORMATION	INTERLAKE FORMATION	INTERLAKE FORMATION		
		INTERLAKE FORMATION	INTERLAKE FORMATION	INTERLAKE FORMATION		
ORDOVICIAN	UPPER	STONY MOUNTAIN FORMATION	STONY MOUNTAIN FORMATION	STONY MOUNTAIN FORMATION		
		STONY MOUNTAIN FORMATION	STONY MOUNTAIN FORMATION	STONY MOUNTAIN FORMATION		
		STONY MOUNTAIN FORMATION	STONY MOUNTAIN FORMATION	STONY MOUNTAIN FORMATION		
CAMBRIAN	UPPER	DEADWOOD FORMATION	DEADWOOD FORMATION	DEADWOOD FORMATION		
		DEADWOOD FORMATION	DEADWOOD FORMATION	DEADWOOD FORMATION		
		DEADWOOD FORMATION	DEADWOOD FORMATION	DEADWOOD FORMATION		
PRE-CAMBRIAN			PLUTONIC AND METAMORPHIC ROCKS			

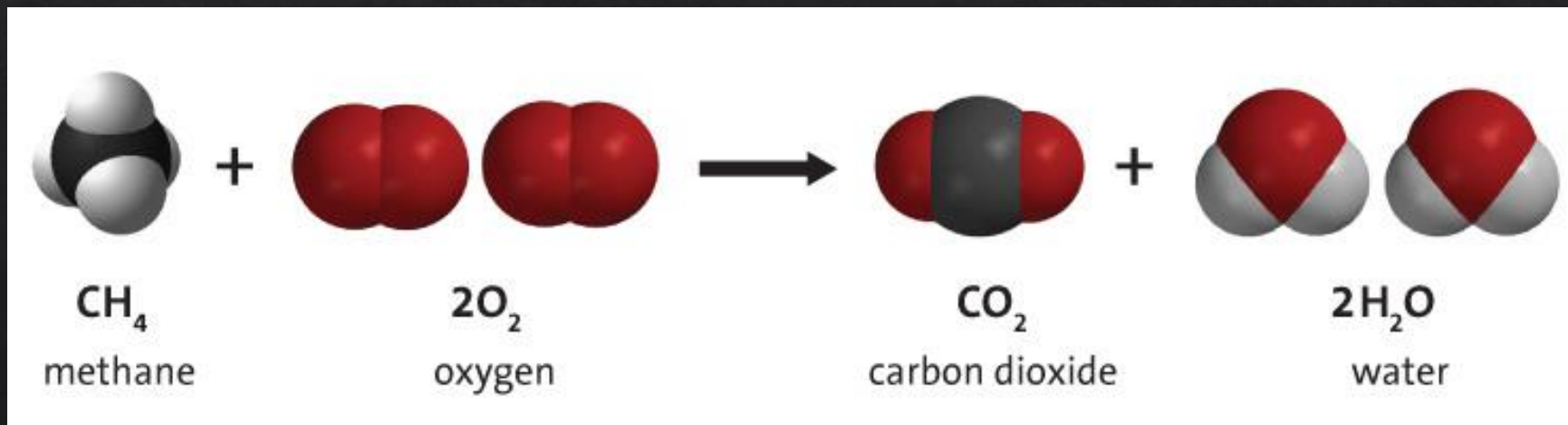
Oil Extraction Technology

- ◆ Horizontal drilling
 - ◆ Has helped us reach harder to get to rock formations.
 - ◆ Made the Bakken Formation one of the main producers of oil in North Dakota.



Natural Gas and Flaring

- ◇ Natural Gas is flared to prevent Methane from being released into the atmosphere.
- ◇ Higher flare rates are achieved in areas that are remote and not close to a processing facility.
- ◇ Dissolved gases in the oil are separated due to pressure changes as it is brought to the surface.
- ◇ Methane → Carbon Dioxide and Water



What Exactly is Light Pollution?

- ◇ Light Pollution: light from cities, vehicles, etc., that makes it difficult to see things in the sky (such as stars) at night ~ Merriam Webster Dictionary
- ◇ I encountered many sources of light pollution while conducting research in the field.
- ◇ Sky-glow is a great indicator of light pollution in the area.
- ◇ Flaring produces light pollution, and very noticeable sky-glow affects.



North Dakota and The Surrounding Area at Night



Methods-Study Sites

- ◆ The Five Study Sites were New England, Halliday, Keene Township, Killdeer, and Williston.
- ◆ These study sites were chosen to represent a variety of both non active oil field site's and active oil field sites.
- ◆ Scouting missions were made during the day to prevent confusion at night.



Methods-Field Equipment

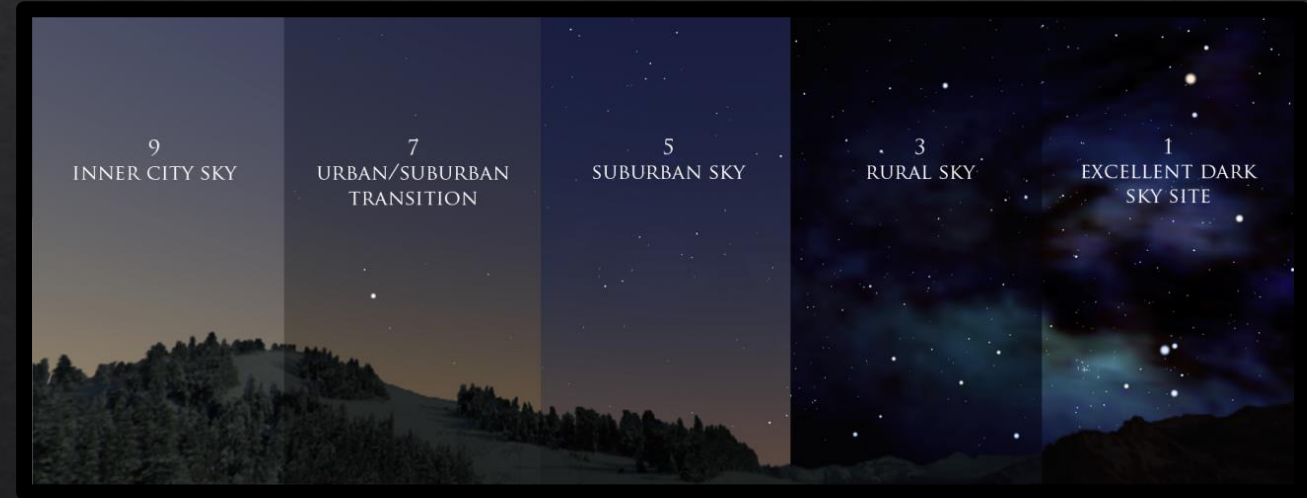
- Left to Right: Kestrel Weather Reader, Unihedron “Sky Quality Meter”, and the Etrex GPS unit.
- Kestrel Weather Reader
 - Used to track weather of the night research was conducted.
- Unihedron “Sky Quality Meter”
 - Used to take Naked Eye Limiting Magnitude Readings
- Etrex GPS unit
 - Used to track each individual stop along route.



Naked Eye Limiting Magnitude

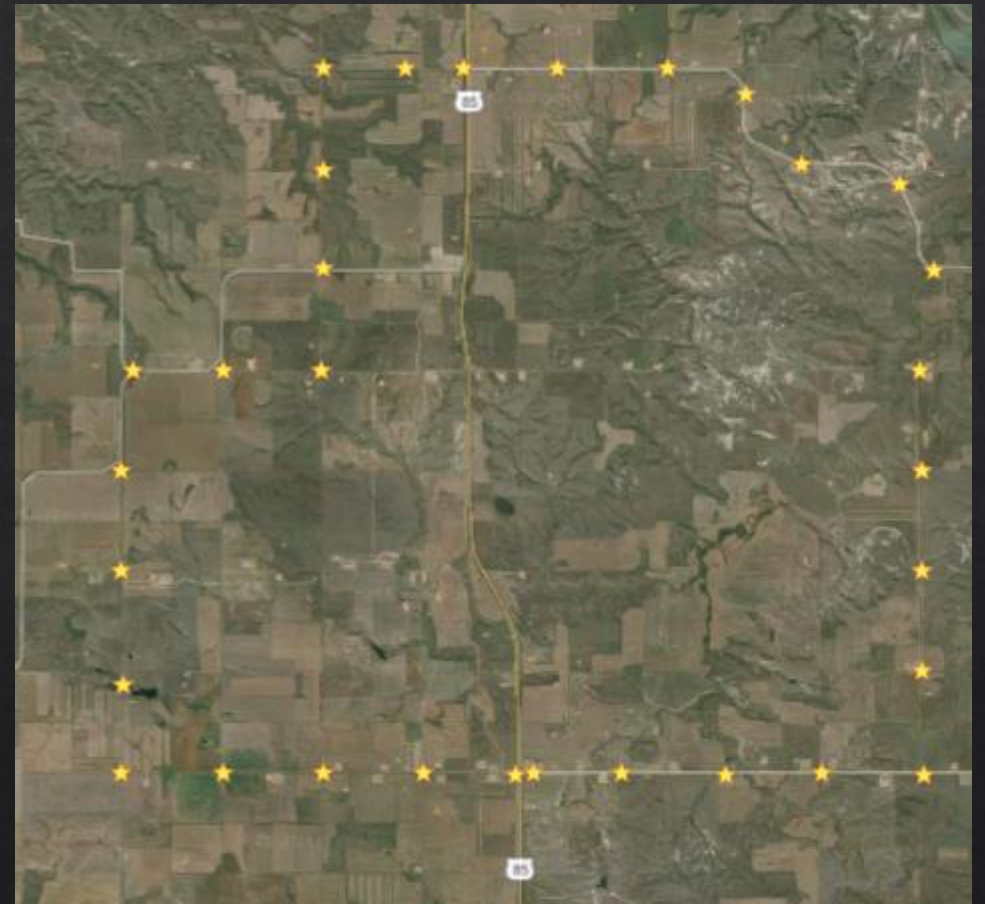
- ◆ **Excellent Dark Sky Site** = 7.6 - 8.0
- ◆ **Typical Truly Dark Site** = 7.1 - 7.5
- ◆ **Rural Sky** = 6.6 - 7.0
- ◆ **Rural/Suburban Transition** = 6.1 – 6.5
- ◆ **Suburban Sky** = 5.6 - 6.0
- ◆ **Bright Suburban Sky** = 5.1 - 5.5
- ◆ **Suburban/Urban Transition** = 4.6 - 5.0
- ◆ **City Sky** = 4.1 - 4.5
- ◆ **Inner-city Sky** = 4.0 – or less.

Bortle Scale



Typical Night in the Field

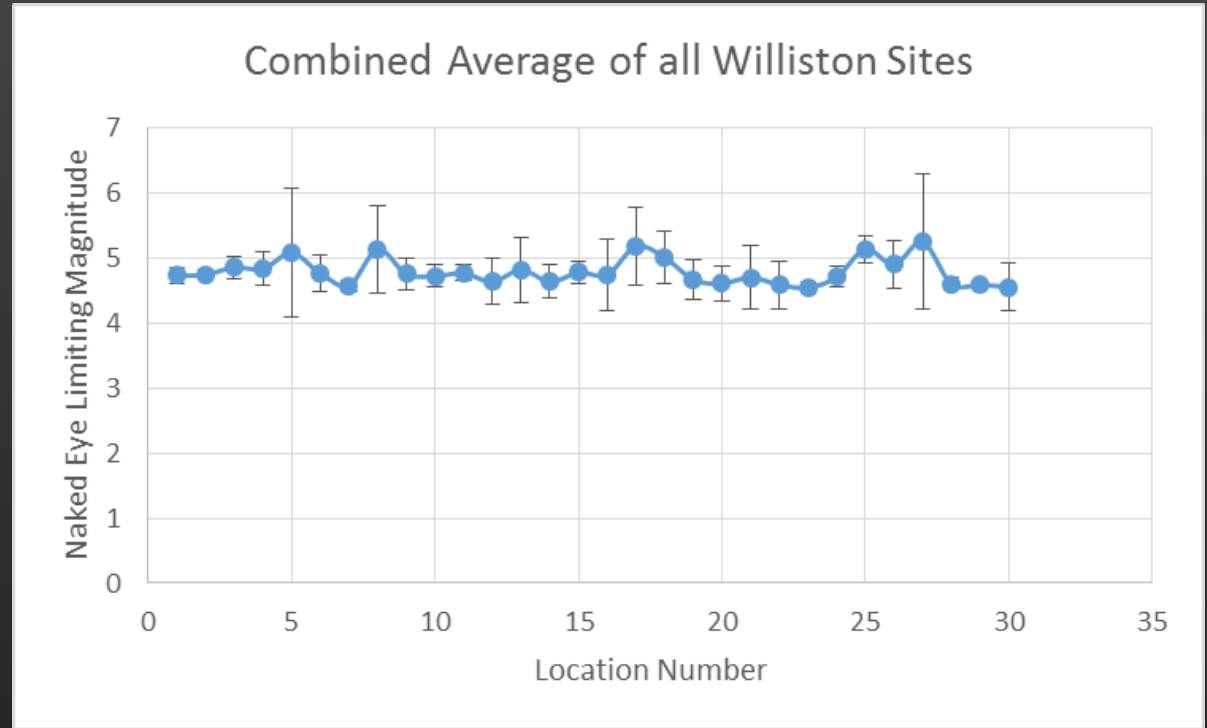
- ◆ Data was collected on favorable nights. A favorable night must consist of the following: no clouds to very little, no fog, no sun or moon, and no other forms of interfering light.
- ◆ Time frames in which readings could be taken were dependent on the sun and moon's rise and set times.
- ◆ All together I drove a total of 3,322 miles over the course of the 16 trips during the summer of 2016.
- ◆ 1,700 data readings were taken over the course of the study.
- ◆ Each Site consisted of approximately 279 readings.



Williston Route

Results

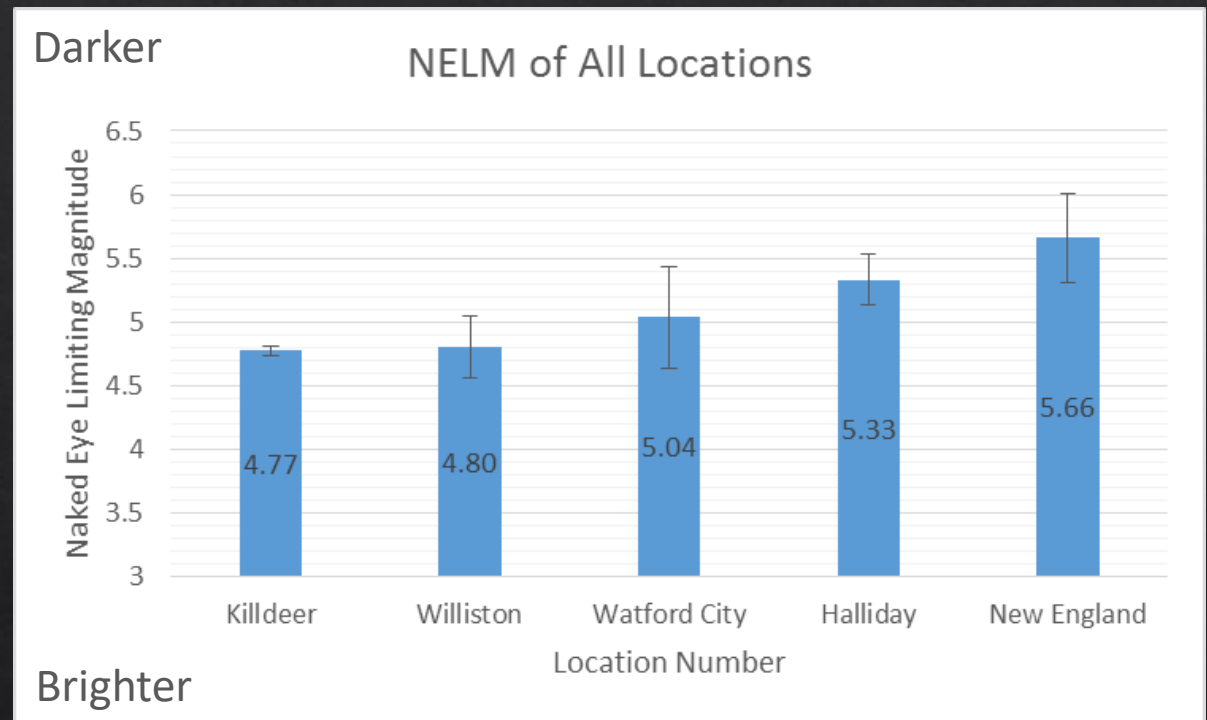
- ◆ This is an example of all three combined dates of the Williston Site.
- ◆ A graph like this one was done for all the sites.
- ◆ As you can see there is some variations with the represented error bars.
- ◆ This could have been done to differences in air particulates in the atmosphere such as dust, or most likely variation in output of flares.



Dates: 8/11/2015, 8/13/2015, 8/15/2015

Results

- ◆ NELM is logarithmic in nature; an increase in a level represents 10times the intensity of the last level.
- ◆ Killdeer is shown as the brightest site.
- ◆ New England is almost 10times darker than Killdeer was.



Conclusion

- ◆ By the use of Naked Eye Limiting Magnitude scale and the Sky Quality Meter by Unihedron we were able to quantify the presence or absence of flaring affects on the visibility of starry skies in Western North Dakota.
- ◆ The data represented that there is a noticeable difference between rural non oil-active sites and oil-active sites.
- ◆ Flares do have an affect on night time viewing of the stars, and may have other affects as well.

Questions?



Expanded-Results

