



Expression of Exploration Targets in High Resolution Satellite Data

Paul Budkewitsch

**Mineral Resources
Resource Management Directorate
Nunavut Regional Office
Indigenous and Northern Affairs Canada**

**Nunavut Mining Symposium
Iqaluit, Nunavut, 5 April, 2016**



Outline

- Airborne and satellite spectral imaging technologies
- Spectral detection of mineralization (gossans)
 - Hall Peninsula Survey (RapidEye)
 - Borden Basin, Central Baffin, Baker Basin (WorldView-2)
- Summary and recommendations for exploration



A brief timeline of optical imaging technology applications in the Canadian Arctic

Prior to 1999: Moderate resolution multispectral satellite data (e.g. Landsat, SPOT). Limited mapping capability.

1999-2003: First airborne hyperspectral campaigns. Early adopters.

2004-2008: Satellite hyperspectral missions (e.g. CHRIS, Hyperion).

Technology demonstrators.

2009-2013 (present): High resolution multispectral satellites offer new capabilities (e.g. GeoEye, WorldView).

Commercial data providers.

Present-future: Higher spectral, spatial and temporal resolution superspectral and constellation programs

(e.g. Planet Labs, Terra Bella)

Migration of sensors to UAV platforms

19/07/2000	RMK Camera not ready			
20/07/2000	RMK Camera not ready			
21/07/2000	MINEO SITE/UK/Finland	07:55	7 916	7 916 MINEO TOTAL FOR UK
22/07/2000	MINEO SITE/AUSTRIA	01:20	1 333	
23/07/2000	MINEO SITE/AUSTRIA	02:50	2 833	4 166 MINEO TOTAL FOR AUSTRIA
24/07/2000	Not film enough for longer missions U/Oberpfaffenhofen			
25/07/2000	Pilots day off/Oberpfaffenhofen			
26/07/2000	Ferry to Finland	02:05	2 083	
27/07/2000	Ferry to Finland	04:30	4 500	
28/07/2000	MINEO SITE/Finland	04:35	4 583	
29/07/2000	HYDO SITE/Finland	06:10	6 166	6 167 HYDO TOTAL OF 9 hours allocated
30/07/2000	Ferry from Finland to Germany/Barth	02:55	2 916	14 081 MINEO TOTAL FOR FINLAND
31/07/2000	DLR TARGETS/GERMANY/Oberpfaffenhofen	01:00	1 000	
01/08/2000	DLR TARGETS/GERMANY/Oberpfaffenhofen			
02/08/2000	Repair of navigation instrument/Oberpfaffenhofen			
03/08/2000	Ferry to Greenland	03:55	3 916	
04/08/2000	Ferry to Greenland HYPERGREEN	08:40	8 666	
05/08/2000	Ferry/Bad weather HYPERGREEN	03:50	3 833	
06/08/2000	MINEO SITE/GREENLAND	03:35	3 583	
07/08/2000	HYPERGREEN SITE	05:40	5 666	
08/08/2000	Ferry to Iceland	04:25	4 416	
09/08/2000	Pilots day off			
10/08/2000	HYPERGREEN SITE	04:20	4 333	
11/08/2000	HYPERGREEN SITE/Ferry to Iceland	06:50	6 833	21 246 HYPERGREEN TOTAL OF 32 allocated
12/08/2000	Ferry from Iceland to Augsburg/Germany via Glasgow	07:45	7 750	28 996 MINEO TOTAL FOR GREENLAND
13/08/2000	Aircraft in Augsburg > Oberpfaffenhofen			
14/08/2000	Overhaul of Aircraft/Oberpfaffenhofen			
15/08/2000	Overhaul of Aircraft/Oberpfaffenhofen			
16/08/2000	Replace of damaged propeller/Oberpfaffenhofen			
17/08/2000	Replace of damaged propeller/Oberpfaffenhofen			
18/08/2000	Replace of damaged propeller/Oberpfaffenhofen			
19/08/2000	Ferry to Cordoba/Spain	05:50	5 833	
20/08/2000	Portuguese MINEO SITE/cancelled	01:45	1 750	
21/08/2000	Portuguese MINEO SITE	04:15	4 250	3 166 OUTOKUMPU TOTAL OF 7:30 allocated
22/08/2000	OUTOKUMPU SITE/Portugal	03:10	3 166	16 749 MINEO TOTAL FOR PORTUGAL
23/08/2000	Ferry from Spain to Germany	04:55	4 916	
24/08/2000	GERMANY MINEO SITE/GERMANY/Finland	03:09	3 150	3 150 MINEO TOTAL FOR GERMANY

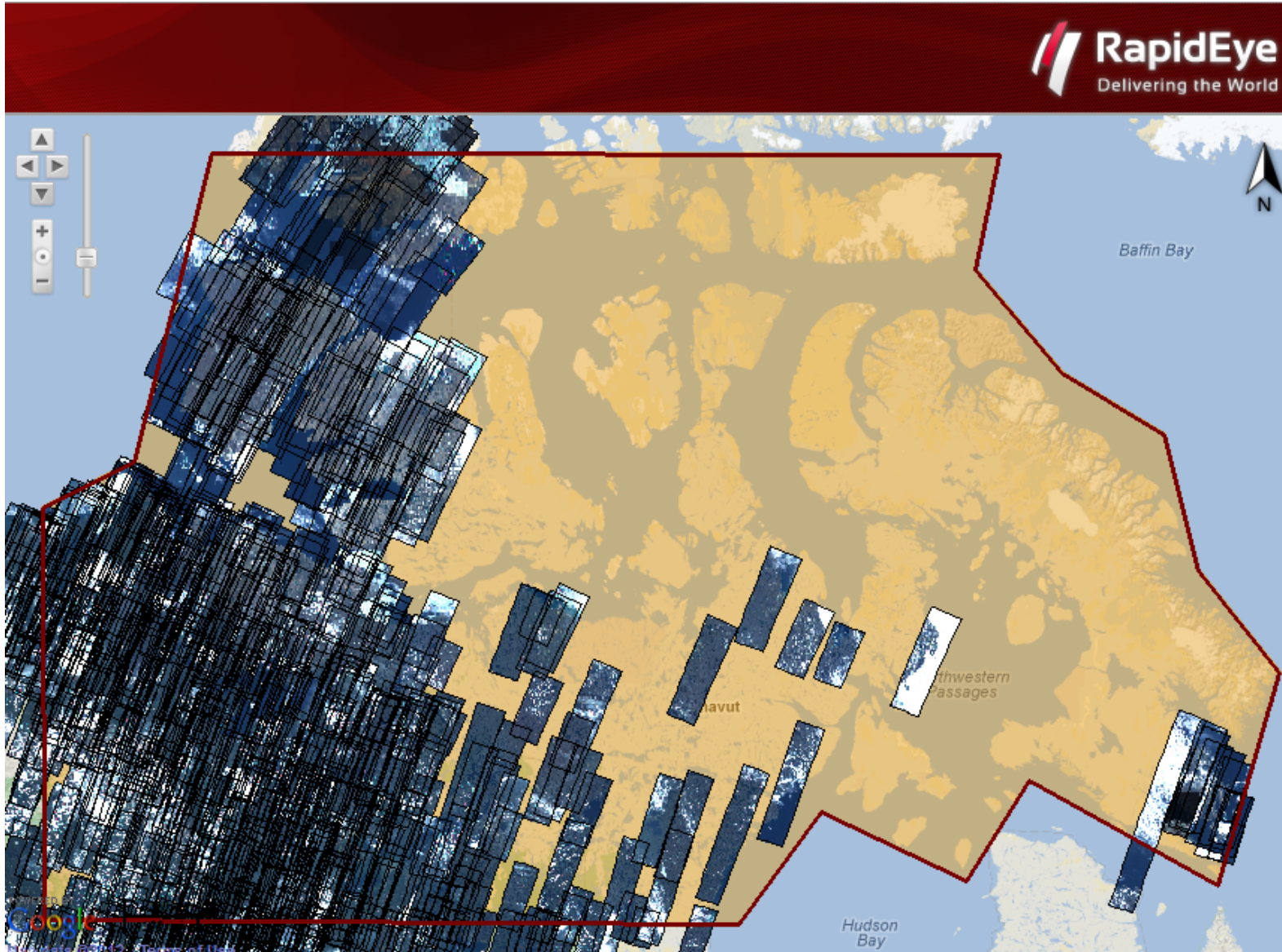


Modern Satellite Technology Solutions

- Large area coverage and rapidly growing archive
- Daily accessibility of any point on the globe
- Low risk of failure, redundancy
- High ground resolution and spectral bands
- Immediate processing of data into customer information



2011-2012 RapidEye™ data coverage of Nunavut, Yukon, and Northwest Territories



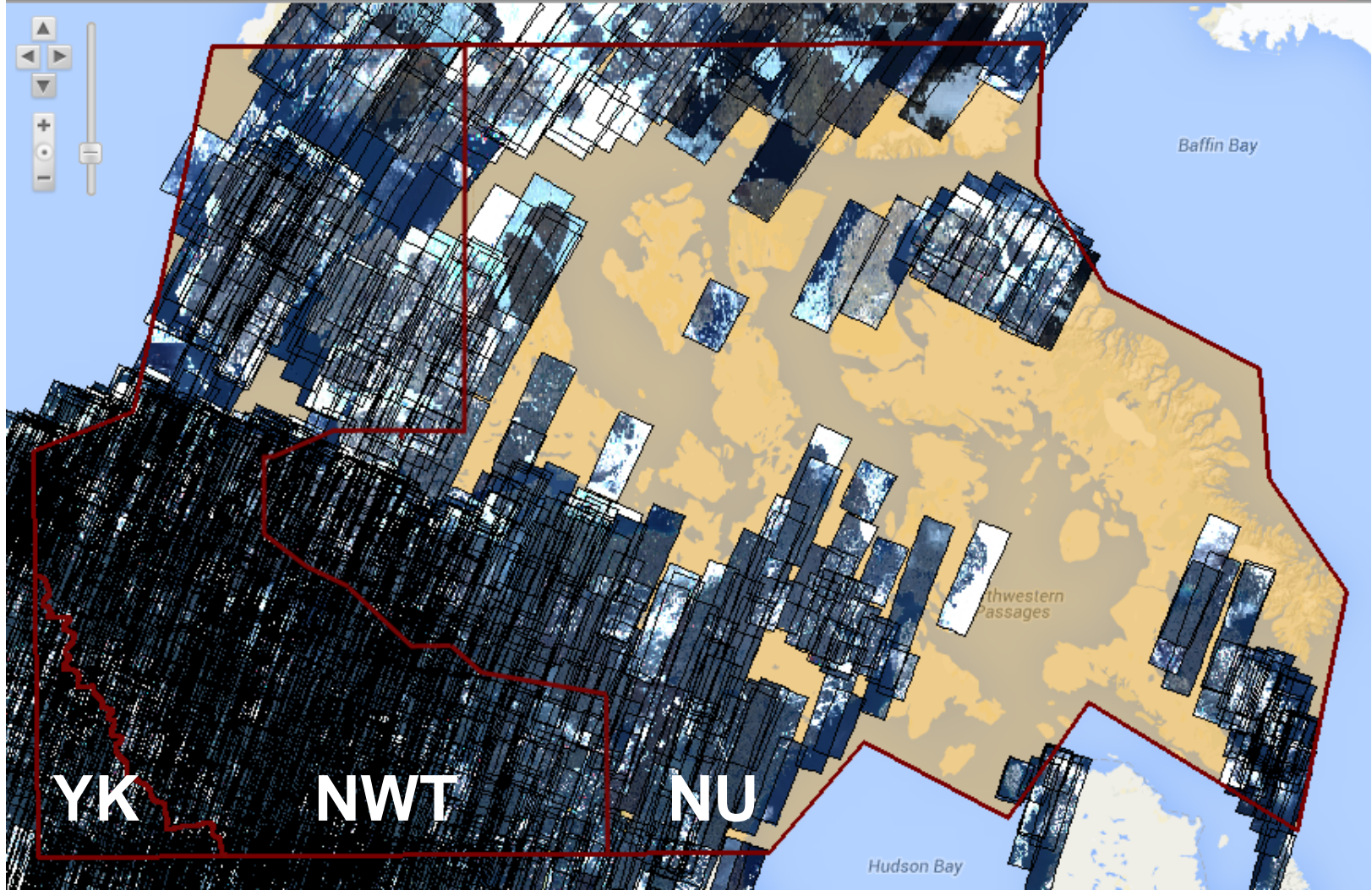


2011-2015 RapidEye™ data coverage of Nunavut, Yukon, and Northwest Territories

EyeFind
Archive Discovery Tool

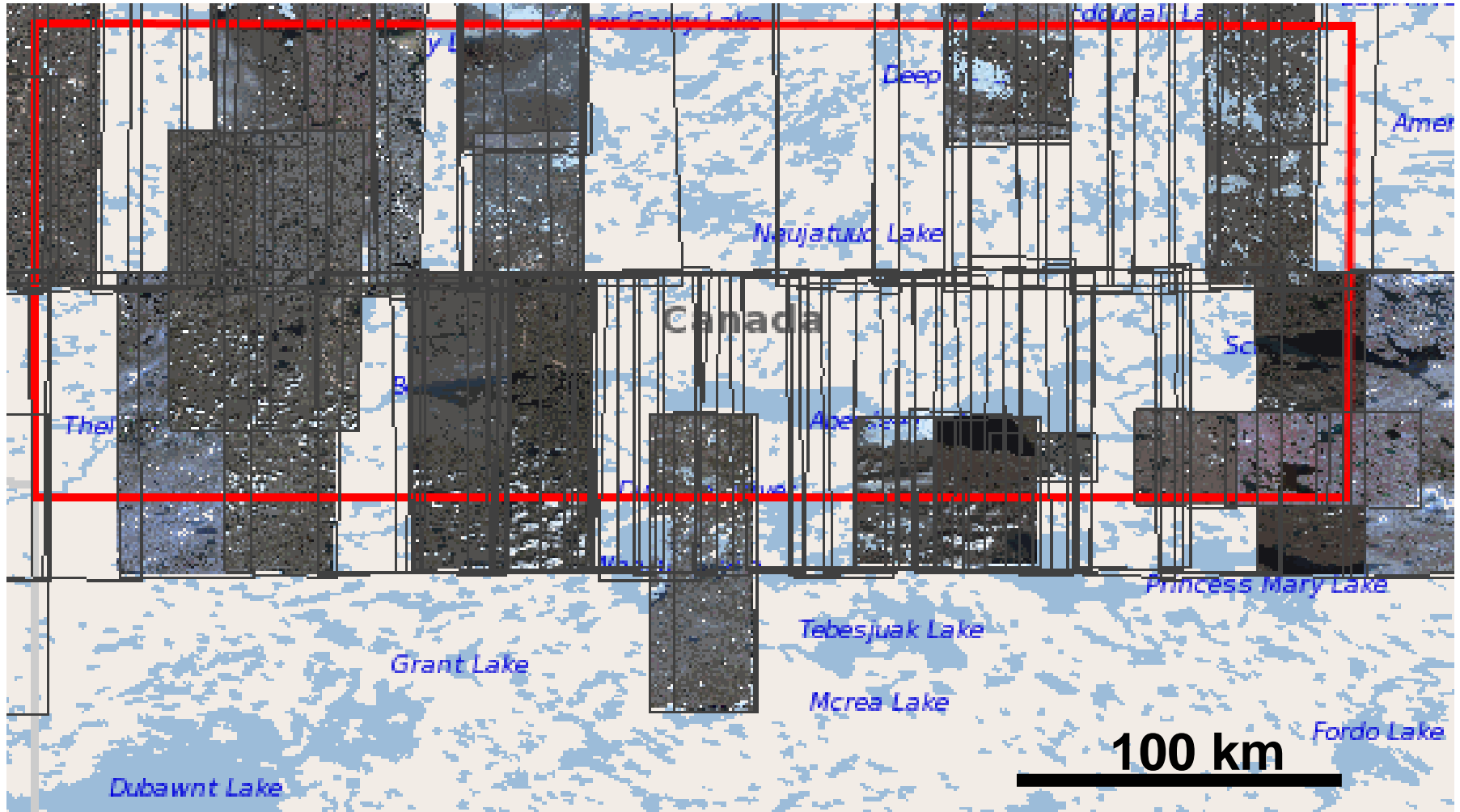


BlackBridge
a Planet Labs Company



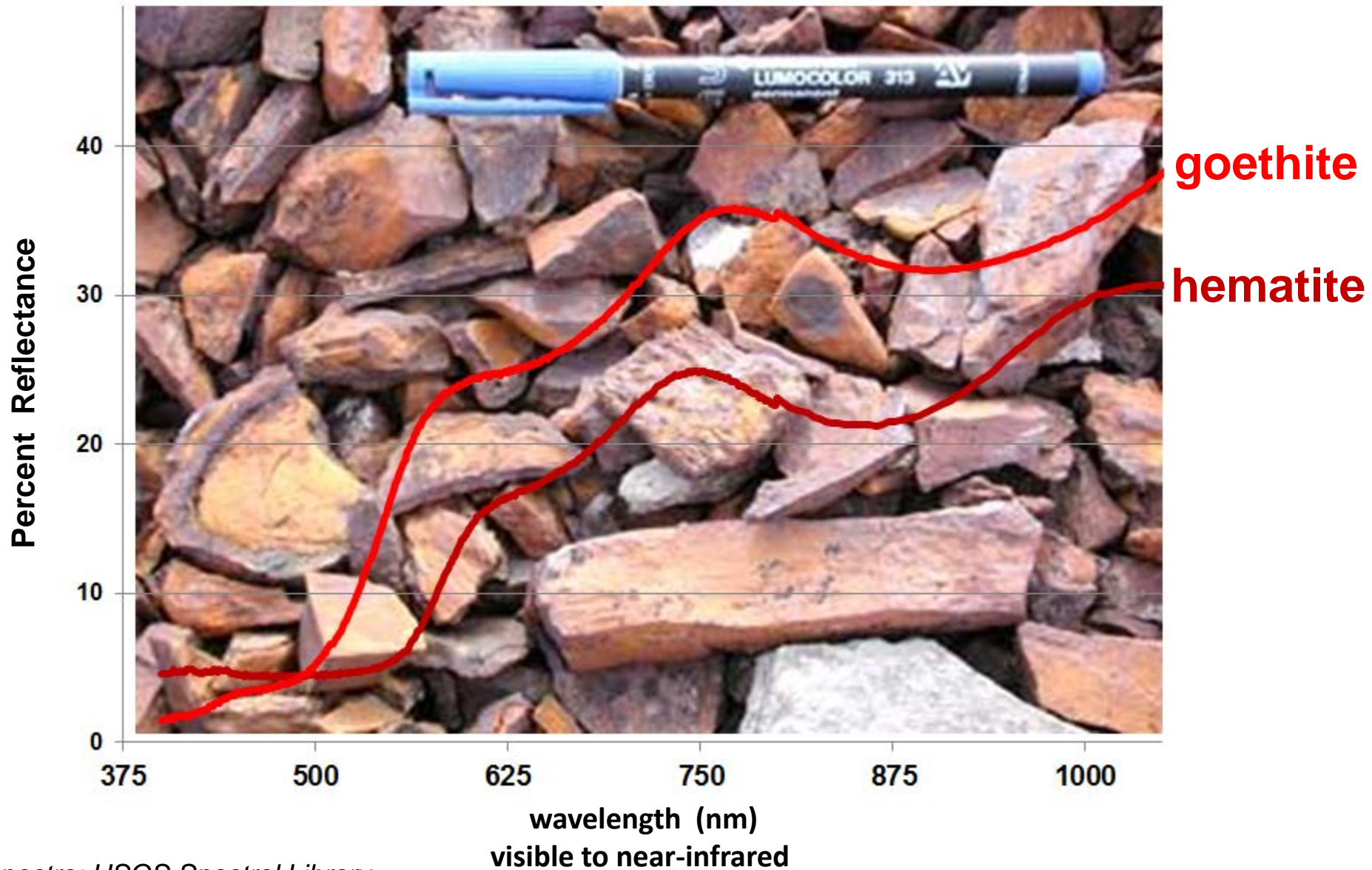


Example of WorldView-2/-3 archival coverage



95% scene coverage; 40% mid-June to the end of August for 2010-2015
(roi = 40,000 square kilometres)

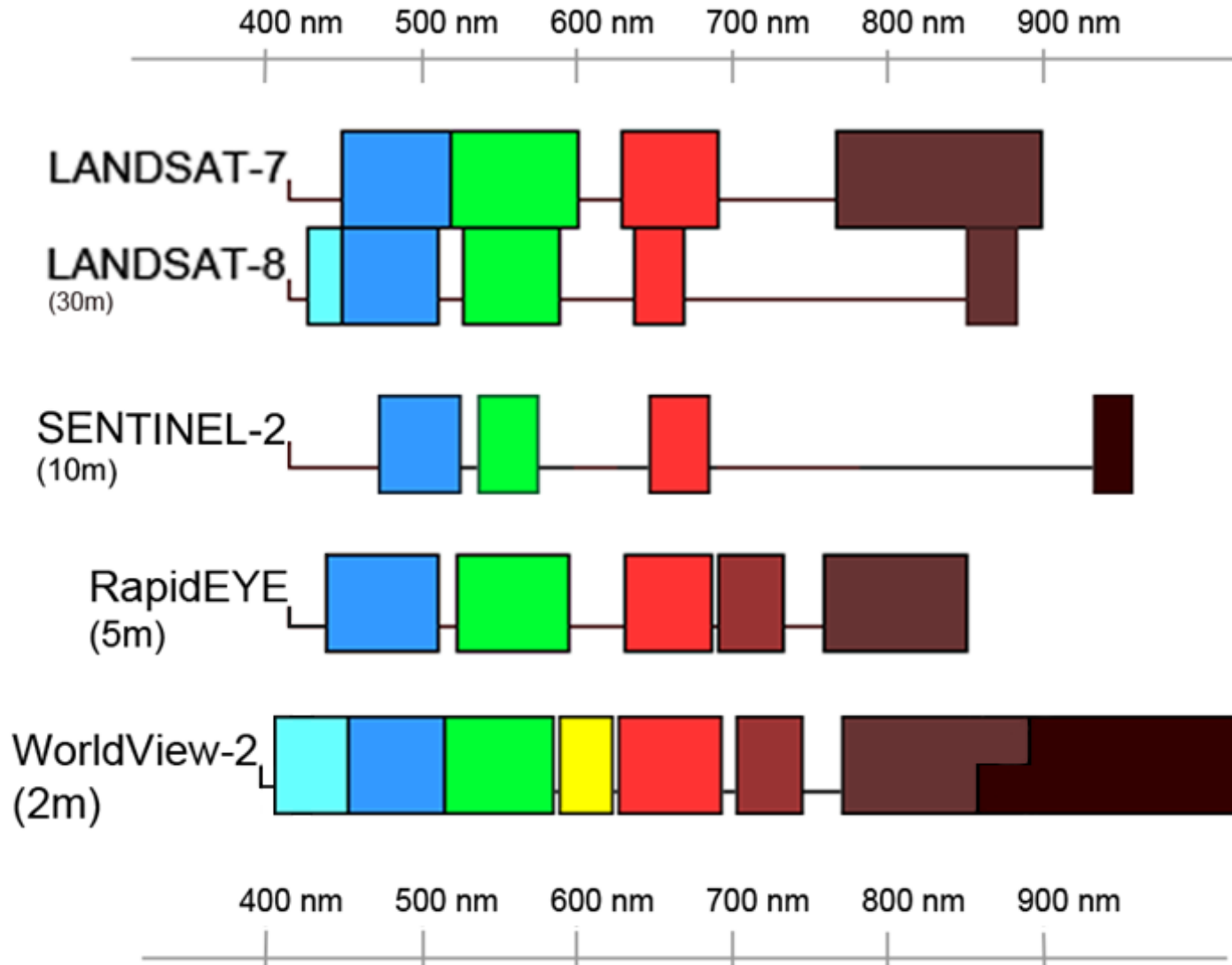
Spectral characteristics of mineral alteration iron oxide/hydroxide minerals: hematite and goethite



spectra: USGS Spectral Library
photo: Borden basin, north Baffin

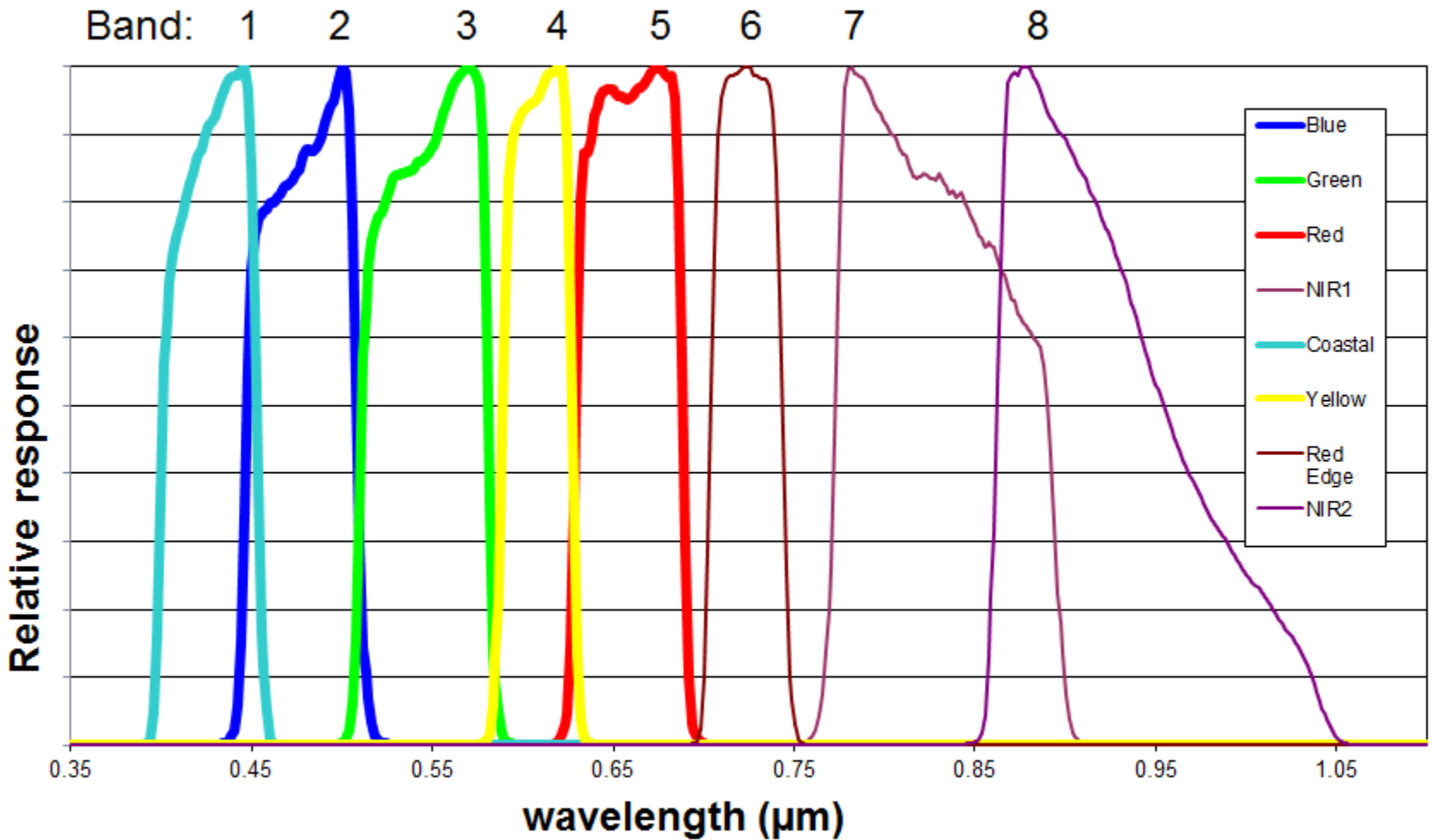


Sensor Bands



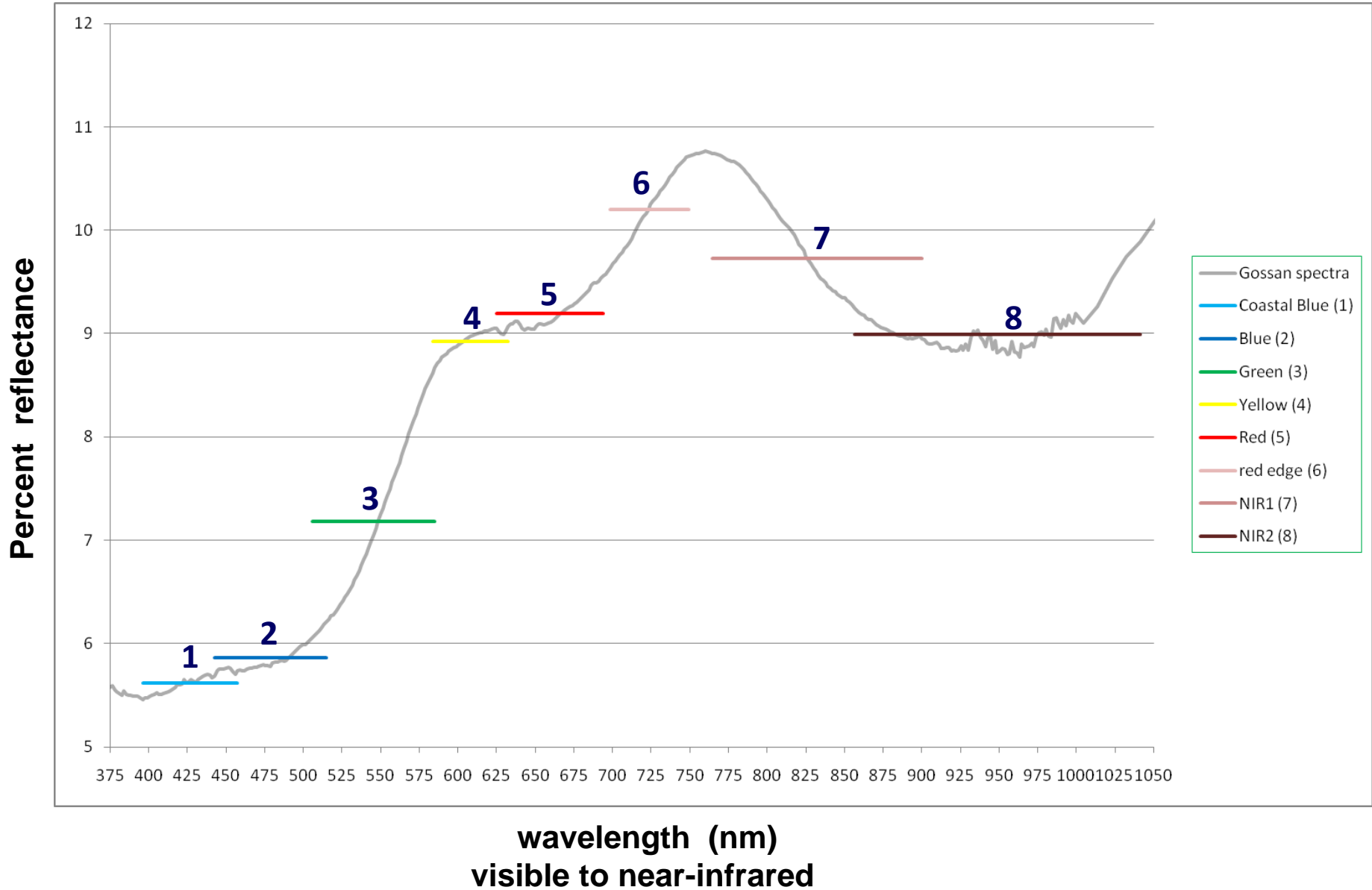


Worldview-2/-3 Spectral Radiance Band Responses



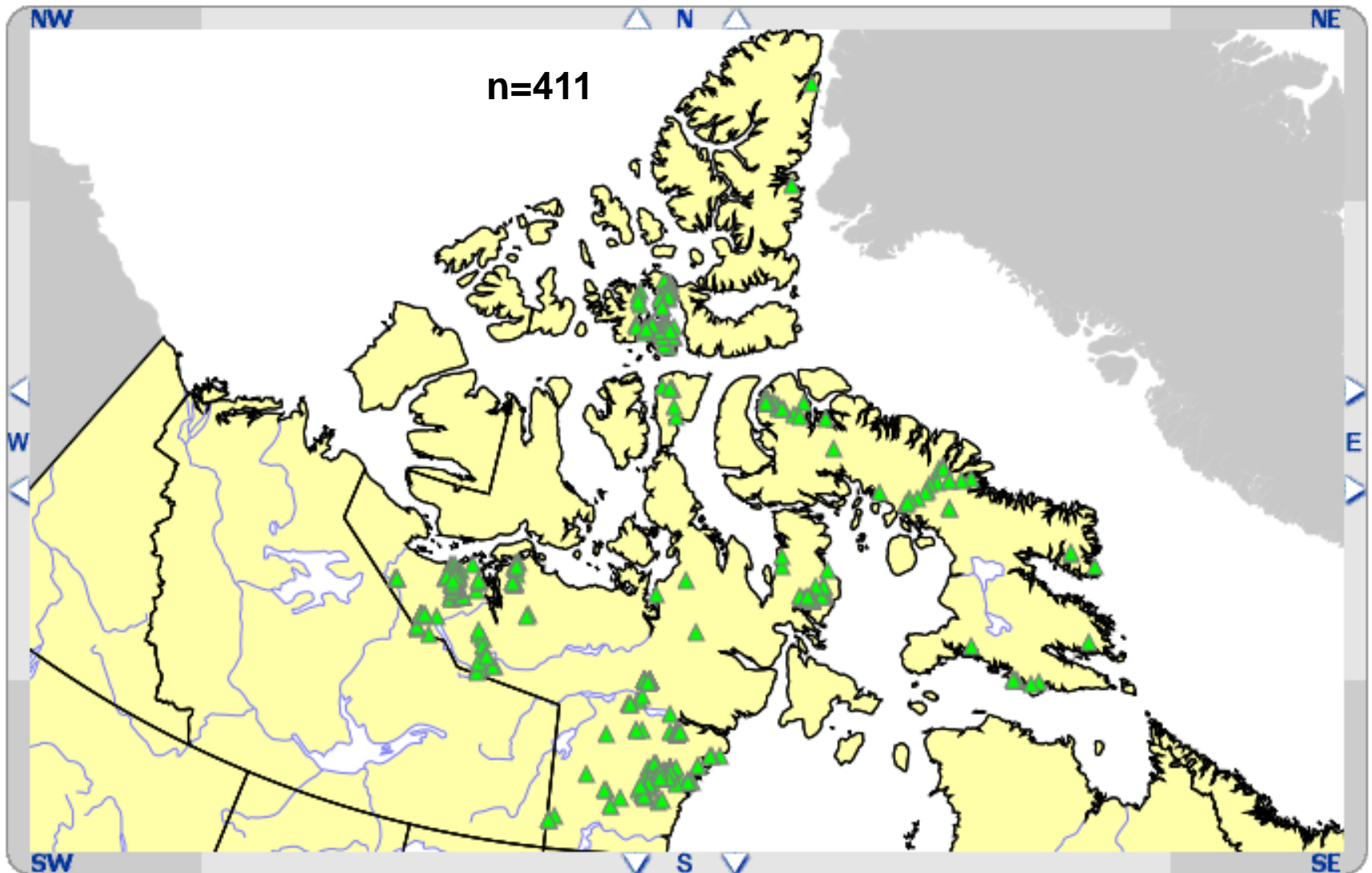


WorldView-2/-3 band sampling of arctic gossan exposure (iron-oxide/hydroxide)





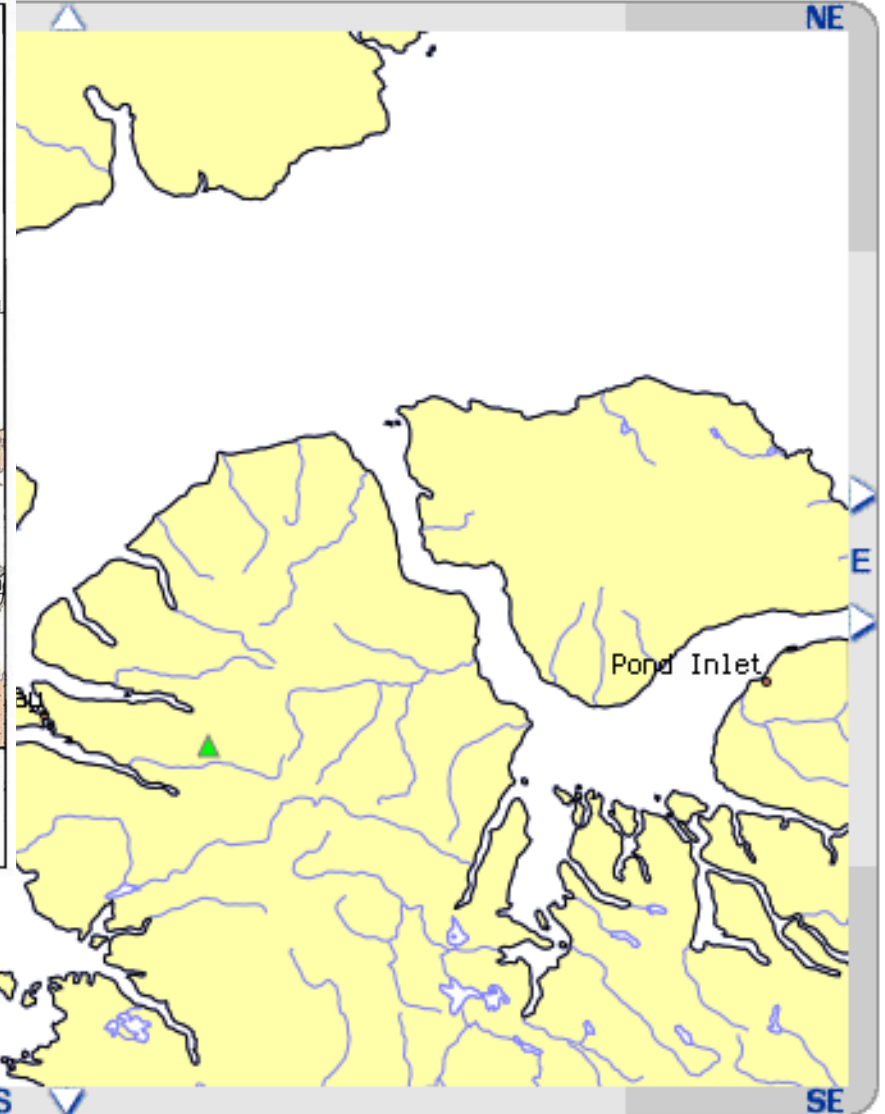
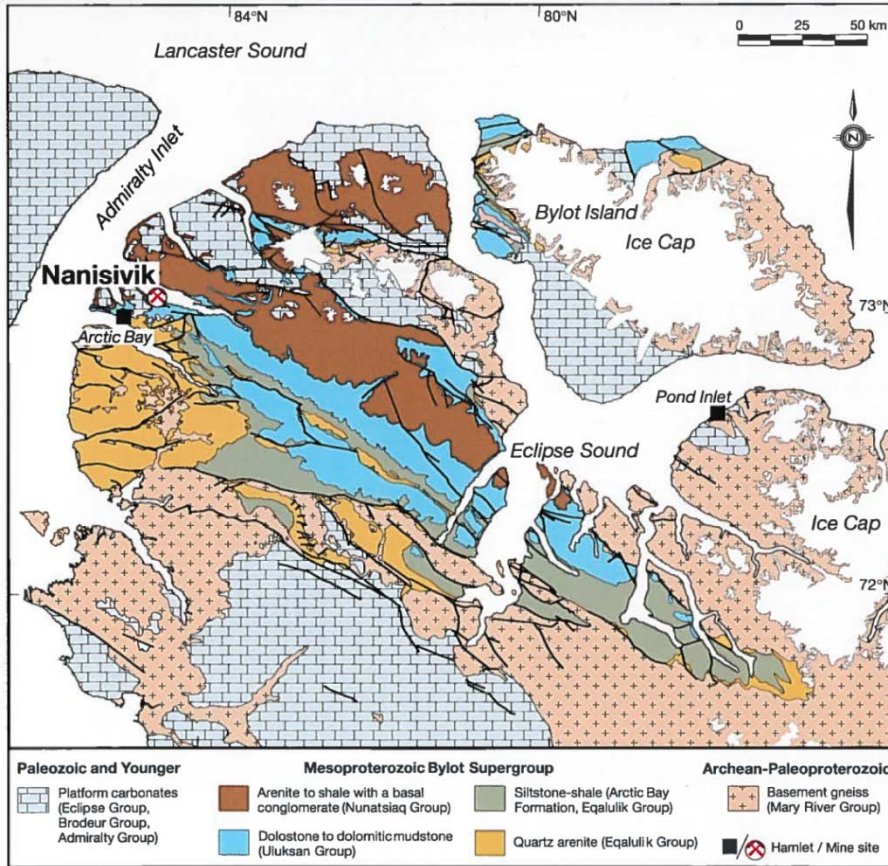
Exploration target: Zinc occurrences in Nunavut



NUMIN occurrence map (<http://nunavutgeoscience.ca>)



Borden Basin: Hawker Creek zinc occurrence



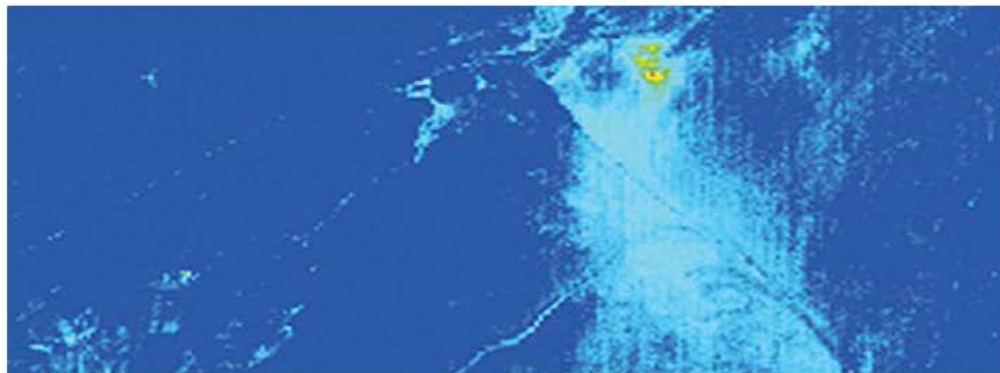
Geological map: Sherlock et al. (2004) Economic Geology
NUMIN occurrence map (<http://nunavutgeoscience.ca>)



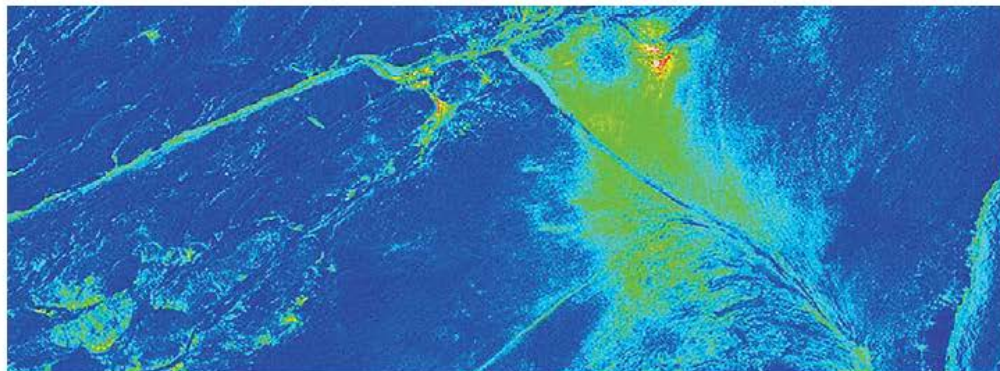
Hawker Creek zinc occurrence

CASE STUDY

Aboriginal Affairs/Mineral Exploration North Canada



AIRBORNE HYPERSPECTRAL TARGETING RESULT



WORLDVIEW-2 TARGETING RESULT

An occurrence of zinc and lead on northern Baffin island, known as Hawker Creek, was surveyed in 1999 using airborne hyperspectral imaging. The data analysis and subsequent field validation work confirmed the presence of associated iron-rich alteration minerals at surface.

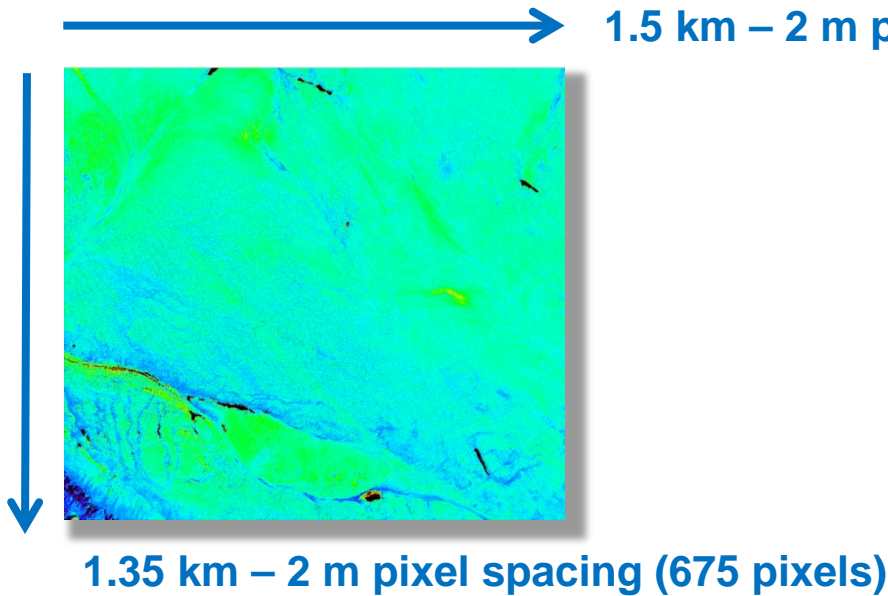
In 2011, Budkewitsch and his team re-imaged the area using WorldView-2 high-resolution imagery.

“WorldView-2’s narrow-band multi-spectral sensors were able to accurately identify occurrences of goethite and iron hydroxide with similar confidence and few false positives, similar to the hyperspectral results, but at a fraction of the cost,” Budkewitsch says.

A repeatable, cost-effective approach



Other matches to gossan spectra



Results:

- Three sites south of Hawker Creek met the criteria with 69, 8 and 1 pixel exceeding the analysis threshold.
- Results represent a consolidated area of interest that would fit within a square 18 m and occupies 0.015% of the total area.
- Three high priority exploration targets were rapidly identified and accurately located.

Data analysis and statistics:

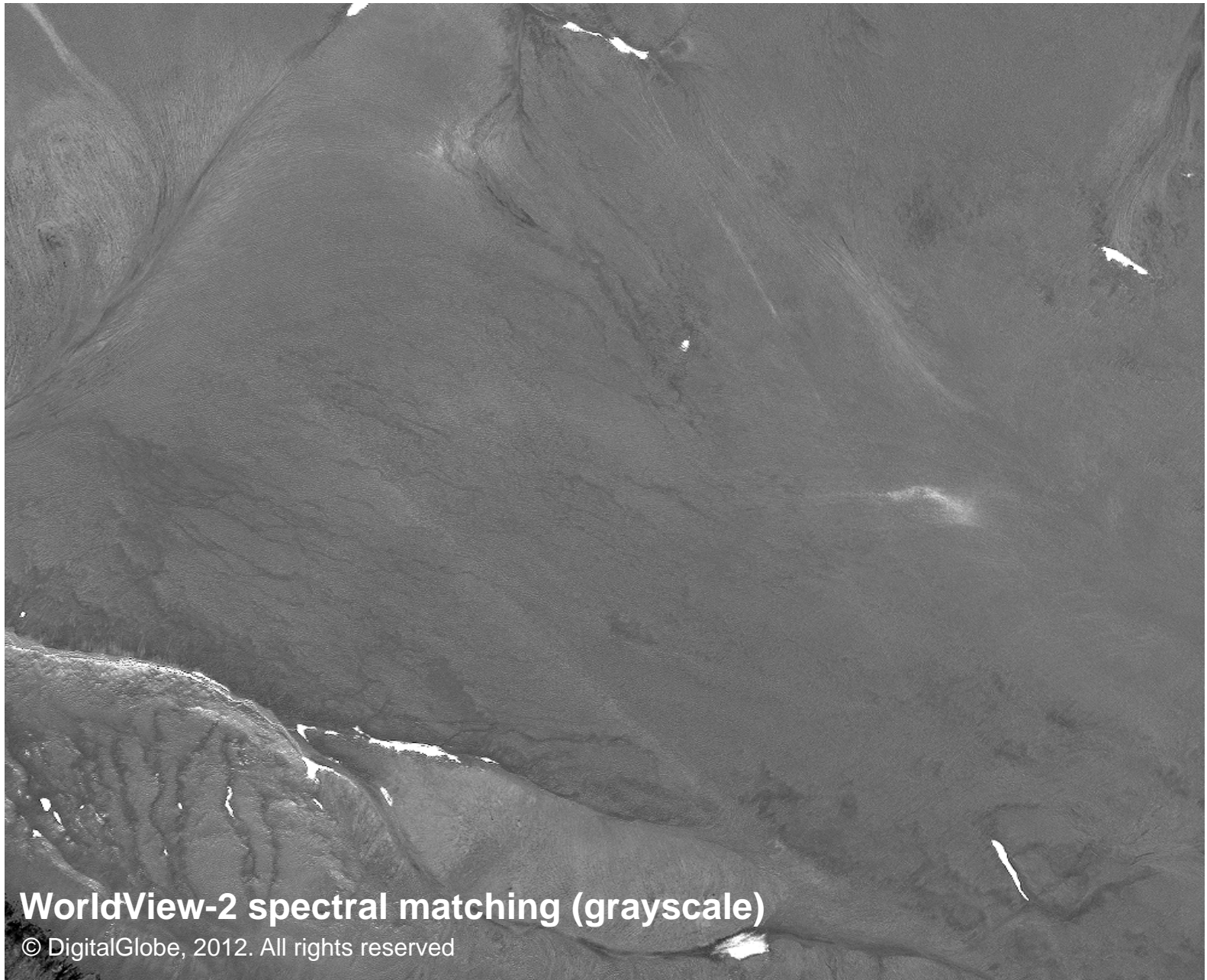
Area = 2 square kilometres
2 m pixel spacing provides
500,000 data points

Band ratio red/NIR (5/8 or 6/8)
yielded best results



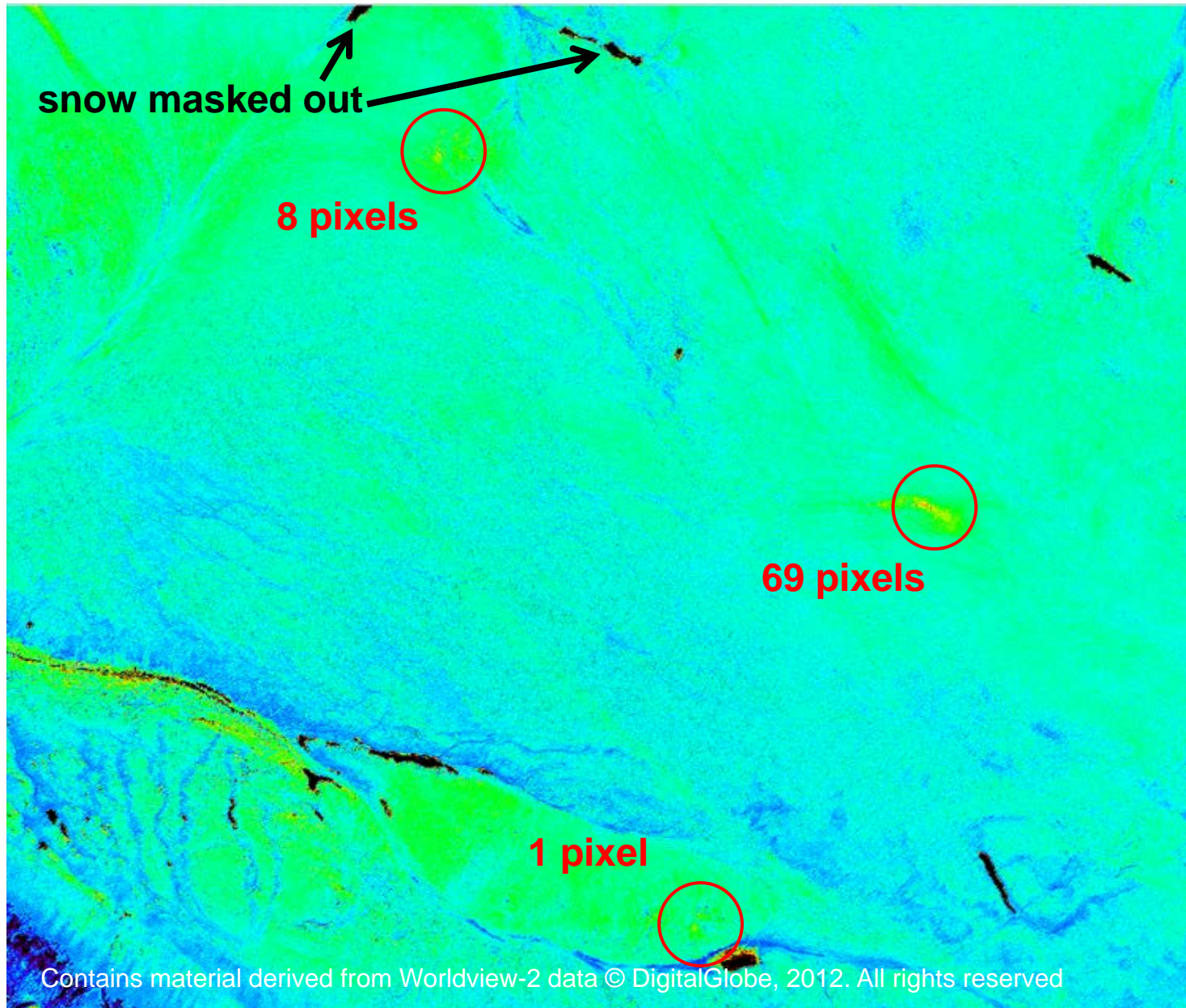
WorldView-2 near true color (5-3-2)

© DigitalGlobe, 2012. All rights reserved



WorldView-2 spectral matching (grayscale)

© DigitalGlobe, 2012. All rights reserved

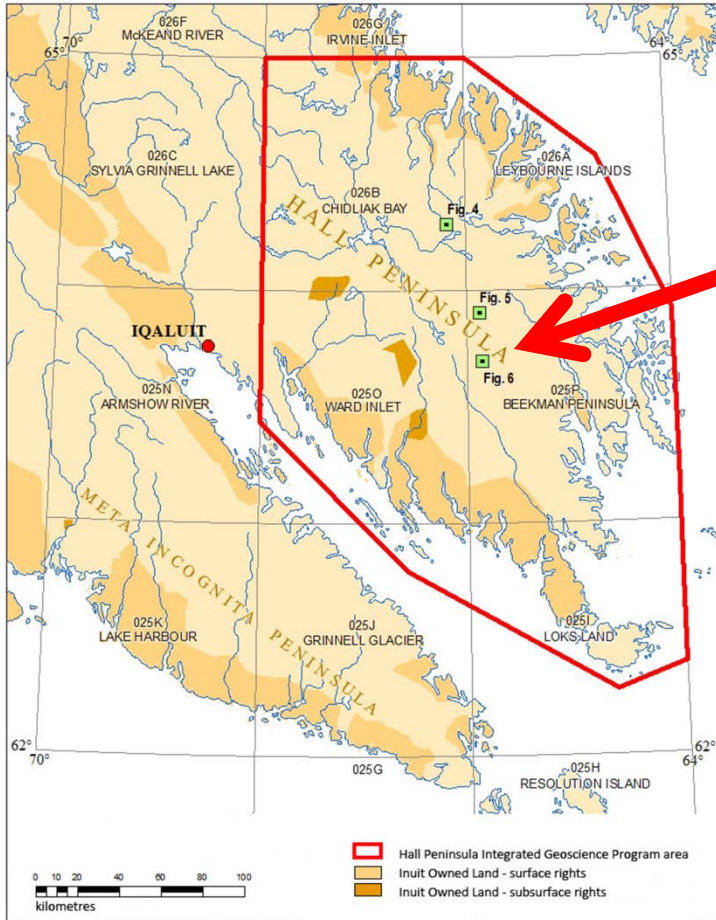


Contains material derived from Worldview-2 data © DigitalGlobe, 2012. All rights reserved

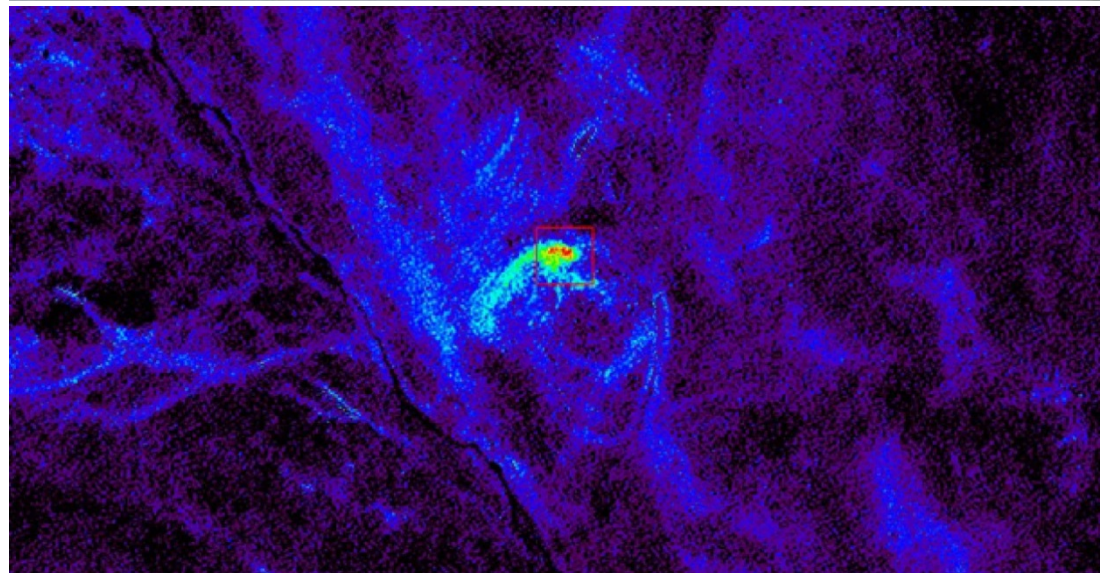
WorldView-2 spectral matching (color LUT)



RapidEYE multispectral band ratio investigations for gossans, Hall Peninsula



Includes material © (2011) RapidEye AG Germany. All rights reserved



1 km

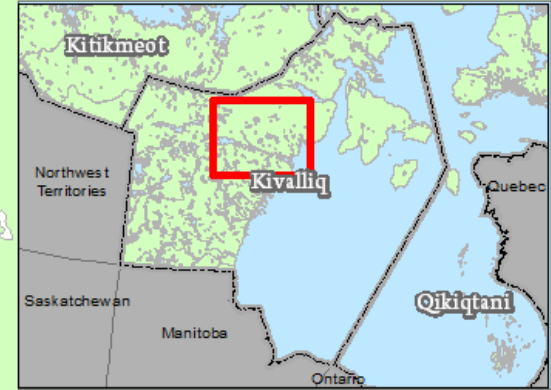
51 sites were investigated. Greatest iron oxide ratios correlated with highest nickel results (>1000 ppm)

Budkewitsch and Sharpe (2015)

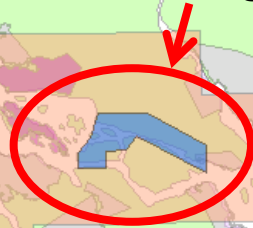
<http://cngo.ca/summary-of-activities/2015/>



Falconbridge Chesterfield Inlet Hyperspectral Survey



North Channel
showing



Project area consists of
24 exploration permits
(3,983 km²)

Chesterfield
Inlet
Assessment Report

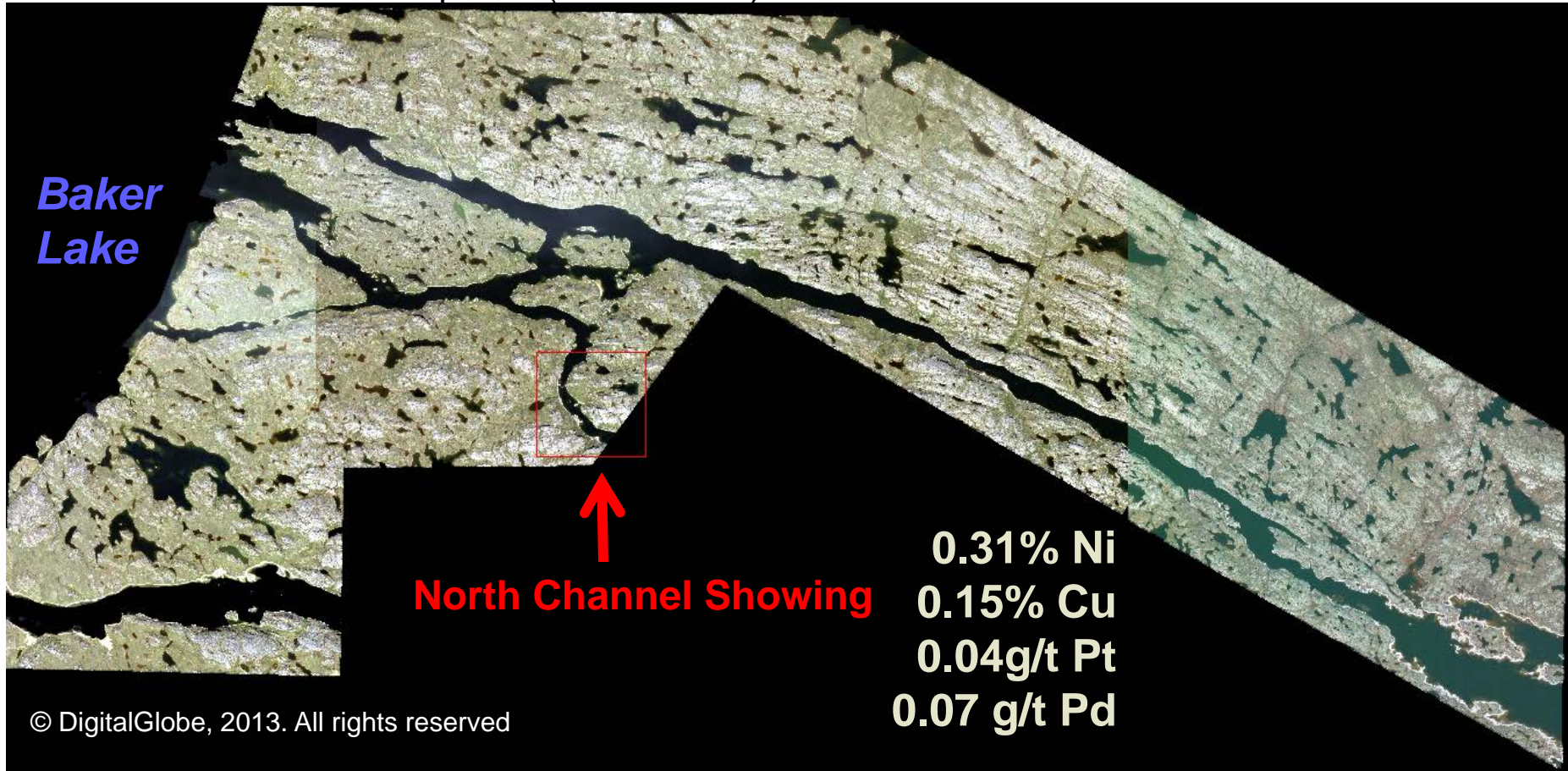
084559

Falconbridge Ltd., (2003)



WorldView-2 multispectral image of Chesterfield Inlet

Near true color composite (bands 5-3-2)

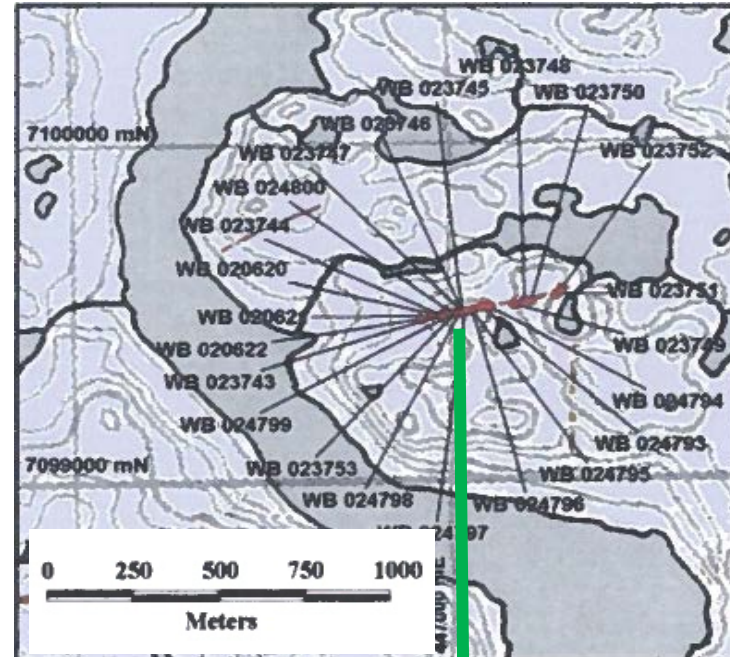
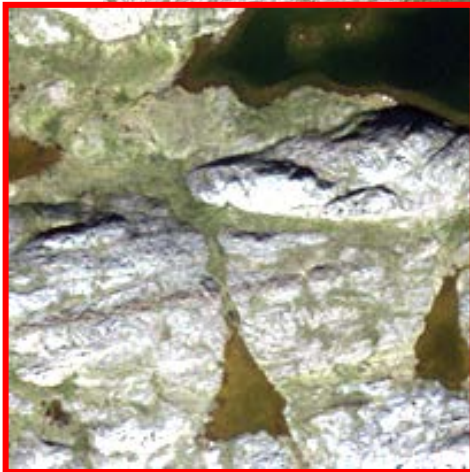


In 2002, Falconbridge Ltd., conducted a hyperspectral survey over priority locations in the Chesterfield Inlet area. Hyperspectral data analysis provided mineralization targets that were mapped and sampled in the field. The survey and field program was \$275,000.



A 4-m wide mineralized gabbro dyke characterizes this location. Described as having a “distinctive rusty brown colour,” the dyke is easily recognized in 2m WorldView-2 data.

© DigitalGlobe, 2012. All rights reserved



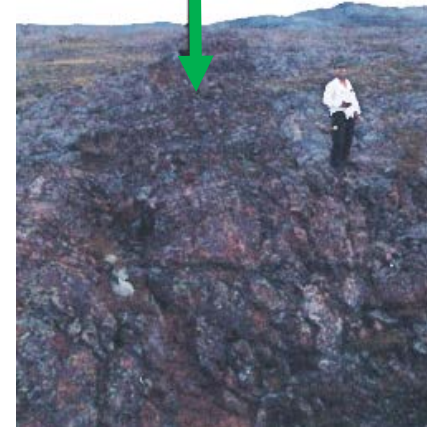
PALEOPROTEROZOIC

 Gabbro Dyke

ARCHEAN

 Granulite

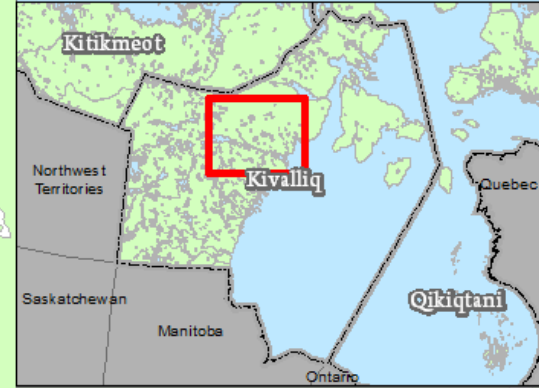
 Lithochemical grab sample location



Near true color composite (bands 5-3-2)



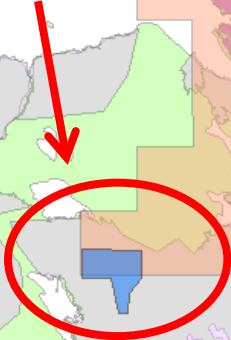
Falconbridge Chesterfield Inlet Hyperspectral Survey



**Tuktu Hills
Gabbro complex**

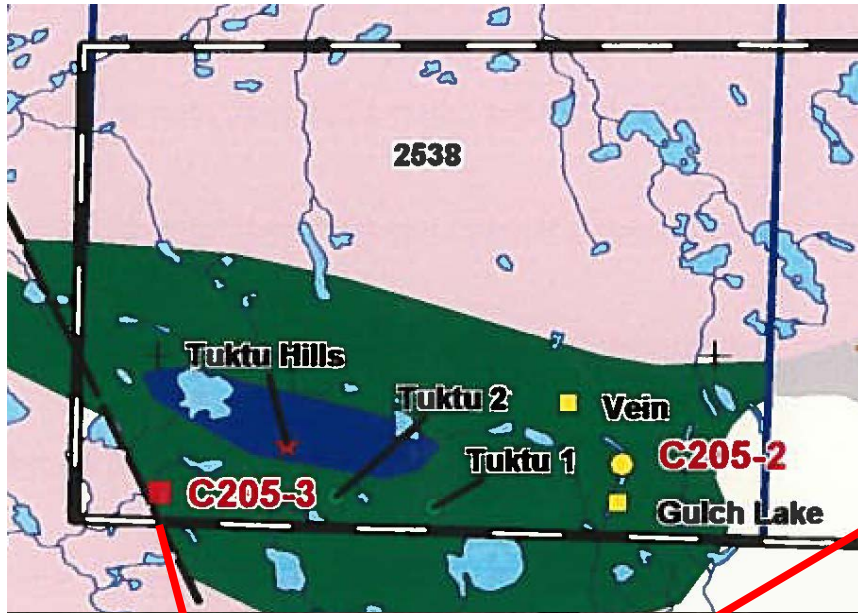
Baker
Lake

Permit 2538



Chesterfield
Inlet

Assessment Report 084559
Falconbridge Ltd., (2003)



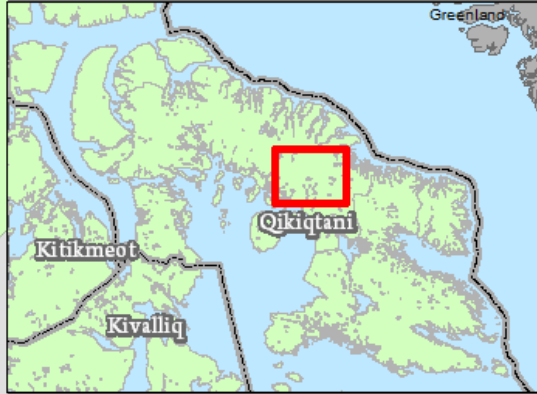
Tuktuk Hills layered gabbroic complex magmatic sulfide mineralization C205-3 grab sample analysis:

0.32% Ni
0.69% Cu
0.02 g/t Pt
0.28 g/t Pd
0.09g/t Au





Falconbridge Bravo Lake hyperspectral survey and field sampling program



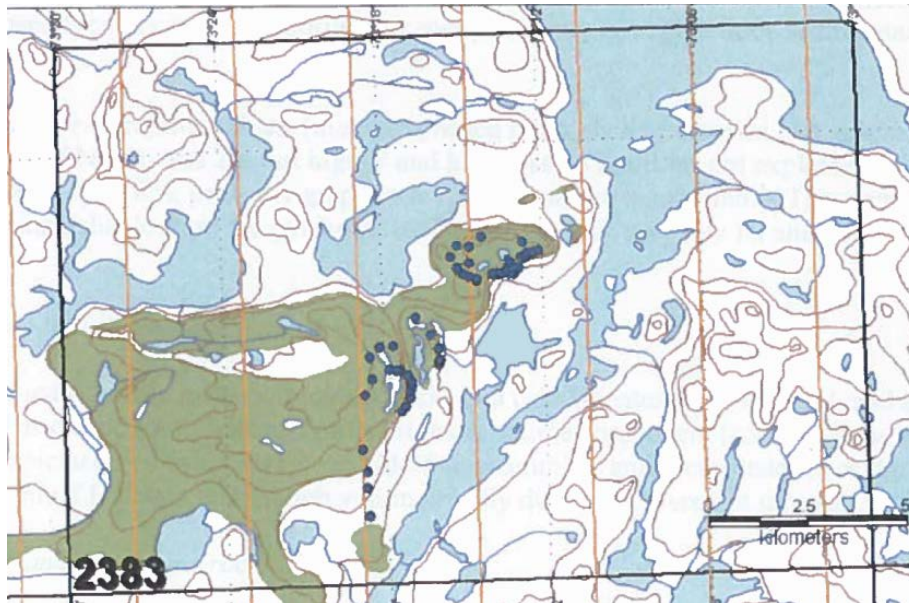
**Project area consists of 22
exploration permits
(5,546 km²)**

Permit 2383

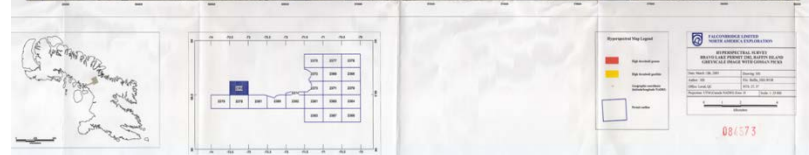




Hyperspectral results produced exploration targets for field sampling program



- Majority of gossans occur in sulfidic iron formation in meta-sedimentary units of the Piling Group
- Semi-massive to disseminated pyrrhotite + pyrite +/- chalcopyrite +/- sphalerite +/- galena
- Mineralization is locally observed in mafic igneous units of the Bravo Lake Formation



□ Final results were plotted on a gray scale image map and compared with our findings from processing WorldView-2 data for the same area

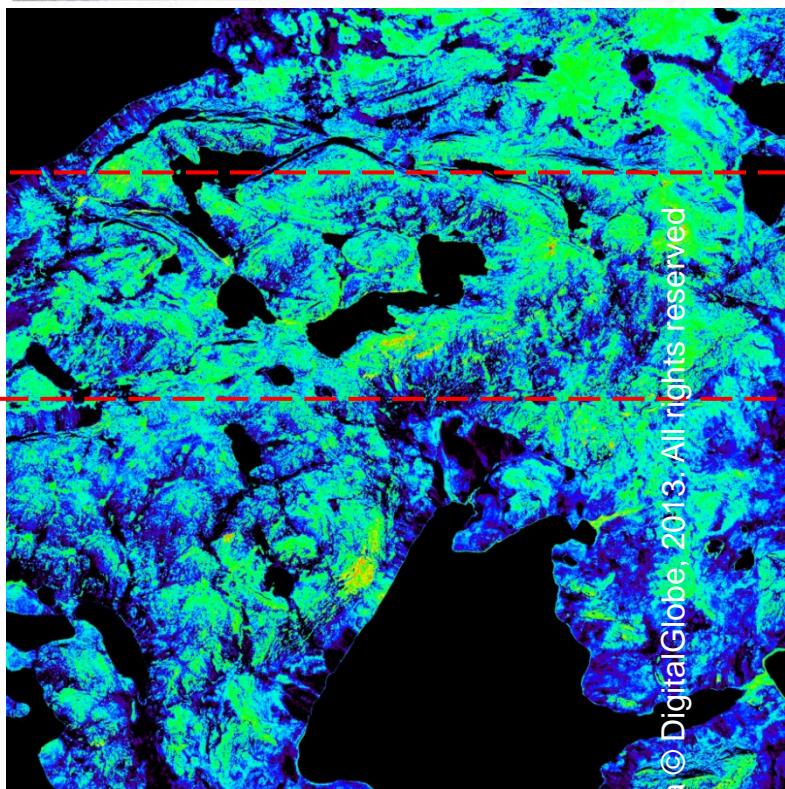


Bravo Lake Permit area 2383

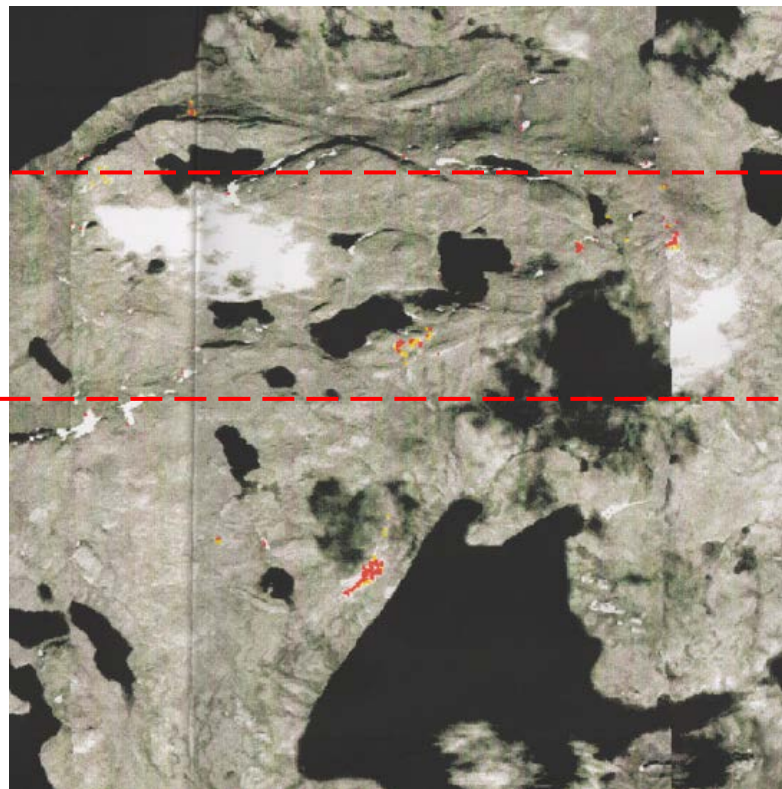
Examination of 4 x 4 km area

WorldView-2 results with AMS-1 Airborne hyperspectral results

Contains material derived from Worldview-2 data
© DigitalGlobe, 2013. All rights reserved



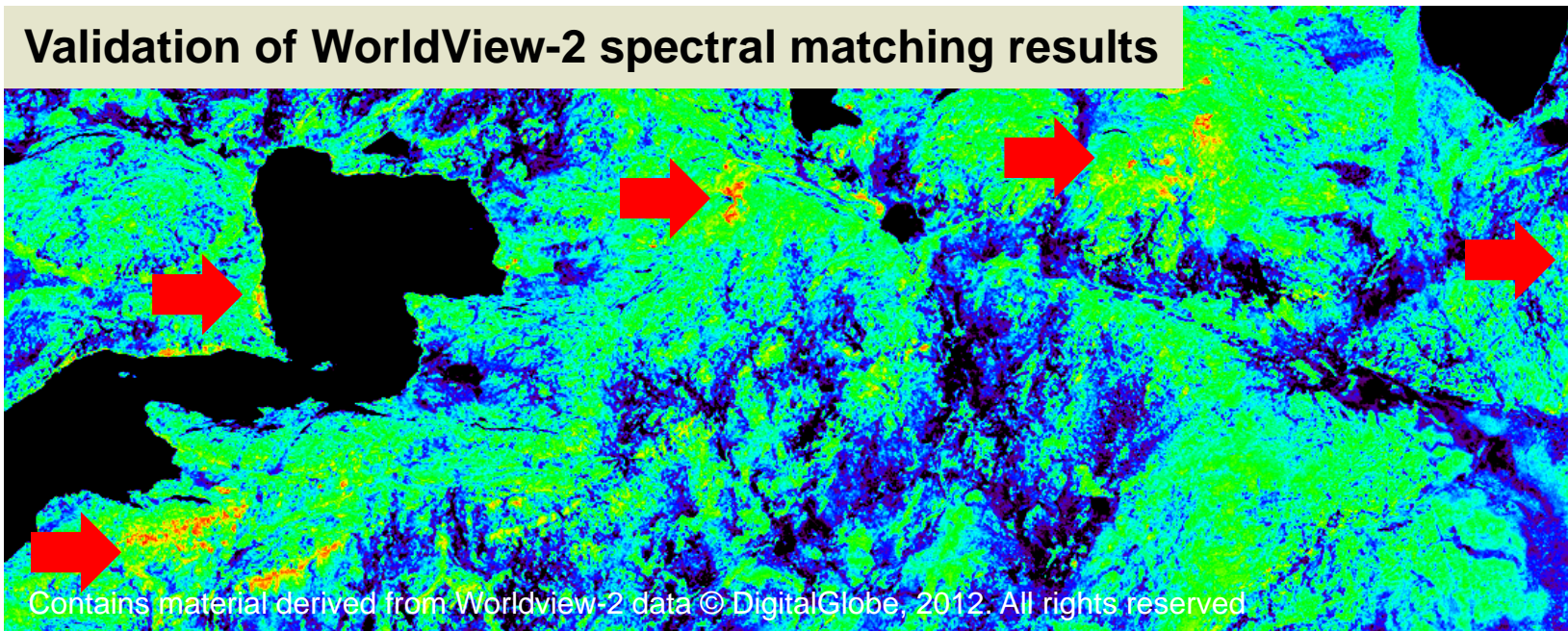
© DigitalGlobe, 2013. All rights reserved





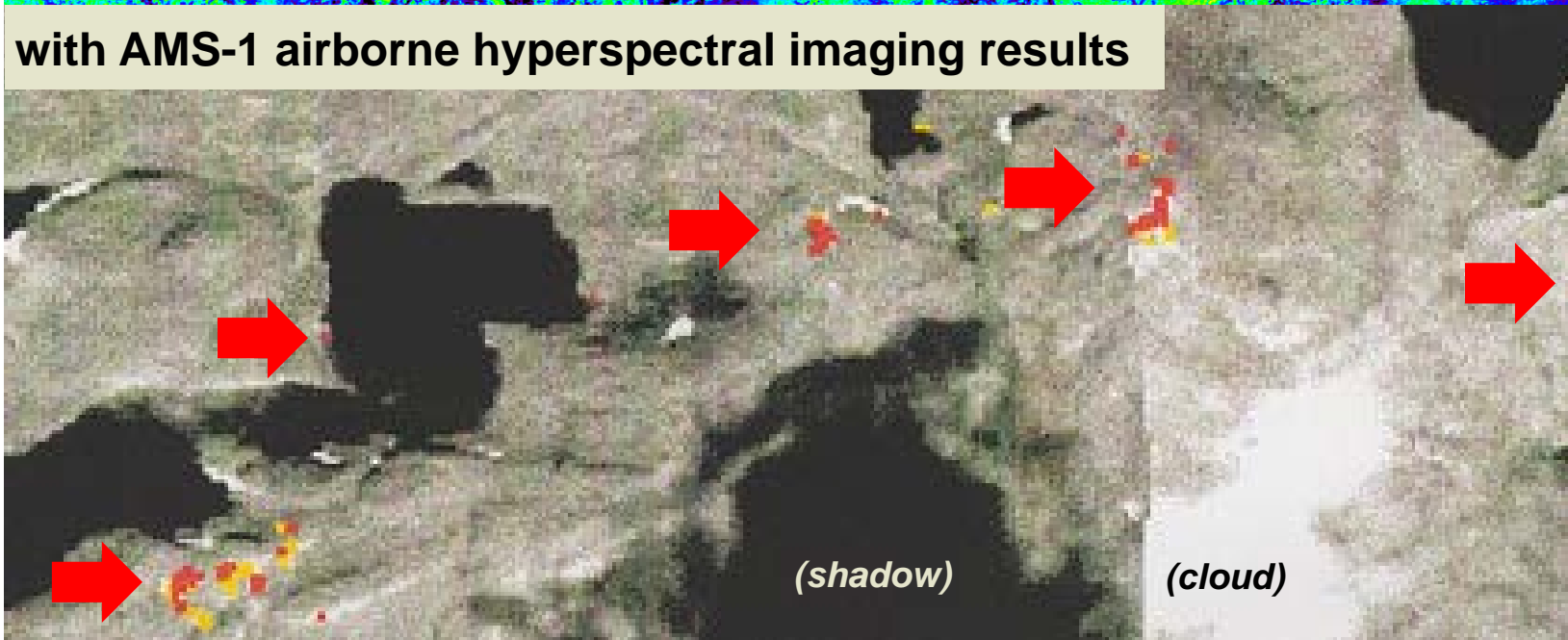
Validation of WorldView-2 spectral matching results

2 m



with AMS-1 airborne hyperspectral imaging results

7 m





Summary – broadband data

- Broadband multispectral sensors with higher resolution enable improved and successful identification of iron rich alteration and iron-bearing mineral assemblages.
- Occurrences and intensity of ferruginous mineral soil and weathered sulfide horizons forming gossans were reliably identified using simple band ratio techniques.
- Reconnaissance exploration surveys over very large regions are feasible with this approach.



Summary – high resolution data

- High resolution multispectral satellite sensors are able to accurately identify occurrences of iron-oxide/hydroxide gossans associated with sulphide mineralization.
- Prospective targets are reliably distinguished from a variety of background materials (“easy” → “hard”).
- Highly cost-effective for vectoring in on zones (less than 1% of total area) of interest for follow-up ground exploration.
- Exploration in detail of large areas with high resolution satellite data is demonstrated possible with confident results, accelerating exploration programs and reducing risk.



Conclusions and recommendations

- Satellite technology is increasingly advanced, rivaling airborne hyperspectral surveys and enabling accurate detection of gossanous zones and other types of mineral alteration.
- Satellite data archives are becoming vastly extensive “big data” sets with multiple coverage that exceed geoscience requirements, yet the available data is still largely under-utilized.
- Mineral exploration in Nunavut can benefit from satellite data availability and a technology sector responsive to rapid acquisition, even during short snow-free periods, as constellation systems provide higher collection capacity.
- For many exploration uses, improved spatial resolution appears to outweigh higher spectral resolution.
- Data solutions provided from next-generation high resolution sensors, such as WorldView-3, are here today and at lower cost than data solutions provided by airborne hyperspectral surveys.



Acknowledgments



Made possible with funding from **SINED**
Strategic Investments in Northern Economic
Development (CanNor)

Steve Sharpe (INAC)
GIS support

RapidEye™ satellite images are
courtesy of BlackBridge (Planet Labs)

WorldView-2™ and WorldView-3™ images are
courtesy of DigitalGlobe inc.

www.aandc.gc.ca

paul.budkewitsch@aandc-aadnc.gc.ca