

Record 2017/13 | eCat 111041

Summary of imagery analyses for non-natural objects in support of the search for Flight MH370

Results from the analysis of imagery from the PLEIADES 1A satellite undertaken by Geoscience Australia

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GEOSCIENCE AUSTRALIA
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ISSN 2201-702X (PDF)

ISBN 978-1-925297-52-2 (PDF)

eCat 111041

Bibliographic reference: Minchin, S., Mueller, N., Lewis, A., Byrne, G., Tran, M., 2017. Summary of imagery analyses for non-natural objects in support of the search for Flight MH370: Results from the analysis of imagery from the PLEIADES 1A satellite undertaken by Geoscience Australia. Record 2017/13. Geoscience Australia, Canberra. <http://dx.doi.org/10.11636/Record.2017.013>

Version: 1701

Acknowledgements

The authors would like to thank:

We would like to thank the French military intelligence service, and the Centre National D'études spatiales (CNES) for the provision of imagery. We would also like to thank Drs Stephen Sagar and David Hudson from Geoscience Australia for reviewing this record. We honour the memory of those who have lost their lives and acknowledge the enormous loss felt by their loved ones.

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1 Introduction

1.1 Executive Summary

On 8 March 2014, the Boeing 777-200ER aircraft registered as Malaysia Airlines 9M-MRO and operating as flight MH370 (MH370) disappeared from air traffic control radar after taking off from Kuala Lumpur, Malaysia on a scheduled passenger service to Beijing, China with 227 passengers and 12 crew on board.

After analysis of satellite data it was discovered that MH370 continued to fly for over six hours after contact was lost. All available data indicate that the aircraft entered the sea close to a long but narrow arc in the southern Indian Ocean.

On 31 March 2014, following an extensive sea and air search, the Malaysian Government accepted the Australian Government's offer to take the lead in the search and recovery operation in the southern Indian Ocean in support of the Malaysian accident investigation.

On behalf of Australia, the Australian Transport Safety Bureau (ATSB) coordinated and led the search operations for MH370 in the southern Indian Ocean. Geoscience Australia (GA) provided advice, expertise and support to the ATSB in sea floor mapping (bathymetric survey) and the underwater search. In March 2017 GA was subsequently asked to provide advice and scientific expertise in the analysis of satellite imagery (PLEIADES 1A) (©CNES) for the detection of possible floating objects.

1.2 Overview

Geoscience Australia (GA) was asked to assist the Australian Transport Safety Authority (ATSB) in the analysis of a set of four Airbus PLEIADES 1A images. GA received these images for analysis on the 23rd March 2017.

The data was acquired over the Indian Ocean on the 23rd March 2014. The analysis performed by GA was to determine whether the images included objects that were potentially man-made in origin. GA analyses included semi-automatic workflows and a number of potential objects were identified.

The overall location of the study area is shown in Figure 1, and a detailed overview of the four scenes with associated detected objects is shown in Figure 2. Figure 3 details the relationship between the PLEIADES data and other MH370 search-related activities.

The appendix to the report presents a data summary for each of the images. This includes a browse image of each scene, including the object locations, a cross plot of the representative spectral radiances observed in the image, a table of the object locations plus size metrics and an indicative label as to the object's origin. The detected objects are shown in true colour and in a false colour derived from Principle Components Analysis (PCA) to help distinguish objects from their surroundings.

1.3 Findings

- The four images contain at least 70 identifiable objects. The nature of these objects ranges from those that in our assessment are probably natural, through to those that are probably man-made. Using a qualitative scale, we rated 12 of the 70 objects to be “probably man made”. Details of the objects in each image are summarised in Tables 1 to 4 in the Results section below.
- Two objects identified by the French Ministry of Defence in their initial examination of the imagery were detected in this analysis.
- Image PHR_4 (Figure 8) contains the majority of objects likely to be of man-made origin. The detected objects have distinct visual coherence and significant differences in brightness, shape and orientation to their surroundings and other objects in the image. The detected objects also appear to form clusters in the image rather than being randomly scattered across the area.
- A preliminary analysis using semi-automatic statistical classification showed that most of the detected objects exhibited the same spectral character as glint (bright solar reflection) from the water surface in both sunlit and shaded water. Hence these objects couldn't readily be separated from wave glint or other natural phenomena by automated means.
- A comprehensive analysis was conducted using manual visual interpretation.

- The confidence with which we are able to state that the objects observed in the images are unnatural could be increased if we were able to also study other images (from the same instrument and satellite in a similar sea-state) where debris is *not* expected to be found. For this reason, examination of further images is likely to be of value.

2 Methods

2.1 Data

The four scenes are centred around -35 degrees south and 91 degrees east in the southern Indian ocean (Figure 1). The scenes are located approximately 100 km apart from each other at the corners of a rectangular area as shown in Figure 2. Each scene is approximately 25 km x 20 km in size.

The scenes are spatially referenced in geographic latitude – longitude coordinates, WGS 84 datum, and have a spatial resolution of 0.000004 degrees (approximately 0.5 m) in the east-west and north-south directions. The scenes are multi-spectral images consisting of four spectral wavelength bands (blue, green, red and near infra-red spectra) which have been panchromatic-sharpened with a radiometric resolution of 12-bits per band (4096 levels of intensity per band). The data were provided in JPEG2000 format with one html metadata file per image.

An overview (or 'browse') image for image PHR_1 is given in Figure 5, PRH_2 in Figure 6, PHR_3 in Figure 7, and PHR_4 in Figure 8.

2.2 Analysis

The four images were manually investigated using QGIS ® and ENVI © ESRI image analysis software regarding possible unusual objects in the imagery.

Objects were manually and visually assessed for differences to their surroundings and the presence of other similar objects in the image. To assess these differences the object brightness, contrast to surroundings, presence of nearby cloud or shadow, and relationship to wave patterns were taken into account.

A Principal Components Analysis (PCA) was conducted on each image to provide additional visualisation for object detection. PCA is a method of reducing complex data into a simpler form that reduces noise and helps to highlight objects that are different to their surroundings. A display of each detected object in true colour and the associated PCA result is provided in the Appendix. The PCA images are coloured to help highlight the objects from their surroundings.

Size estimates were made for each object, but due to the variance in spatial coherence, these estimates are indicative sizes. For example, Figure 4 describes image object 8 in PHR_3 which seems to comprise of a cluster of bright spatially related points, but a single polygon has been used to determine its extent.

3 Results

3.1 Visual Assessment

The four PLEIADES 1A scenes are all significantly cloud and glint affected.

There are six primary surfaces (spectral groups) found in these data; water, surface glint, cloud (of varying coherence and thickness), cloud shadows, shaded water and shaded glint (See Figure 21, Figure 33, Figure 46, and Figure 58).

An exploratory supervised/unsupervised classification based on the six end members suggested that most objects were grouped into the 'Glint' and 'Shaded Glint' classes. Because these spectral classes occupy a significant fraction of the image area, automated classification techniques perform poorly.

The small number of images, and lack of repeat observations over the area resulted in insufficient data to support a data-driven or computer learning approach. Hence, a comprehensive, manual, visual survey of each scene was undertaken. In support of displaying colour composites of the raw data, a Principle Components Analysis (PCA) was undertaken to reduce the band to band correlation and help highlight objects that differed from their surroundings. Using search windows based on a 500 x 500 grid, over 6,500 grid cells were systematically examined in each image. While all care was taken using the grid cells as a guide, it is conceivable that some objects were missed given the manual nature of the scrolling process.

While the purpose of this assessment was to nominate man-made or 'non-natural' objects, there is sufficient ambiguity in the exact properties of many of the visible objects that many that could be natural in origin are still listed (for example, Figure 29, Figure 34 and Figure 37).

To address this limitation, each object has been allocated a label based on its overall appearance, shape and size. A rating schema ranging from 1 to 5 has been used in which:

1 = 'probably natural' and 5 = 'probably not natural', (that is, probably man-made).

Objects are labelled 1 when, despite displaying an obvious structure and being visible in both the colour composite image and the PCA images, and being distinct from surrounding wave and water patterns, they lack a spatial coherence or the shape is indeterminate.

In contrast, bright objects with a strong rectilinear coherence, and seeming to displace the water around them (especially when in close proximity to similar objects), have been labelled 5. See Table 1, Table 2, Table 3 and Table 4.



Figure 1: Centre point of PLEIADES data (Source: French Military Intelligence Service © CNES)

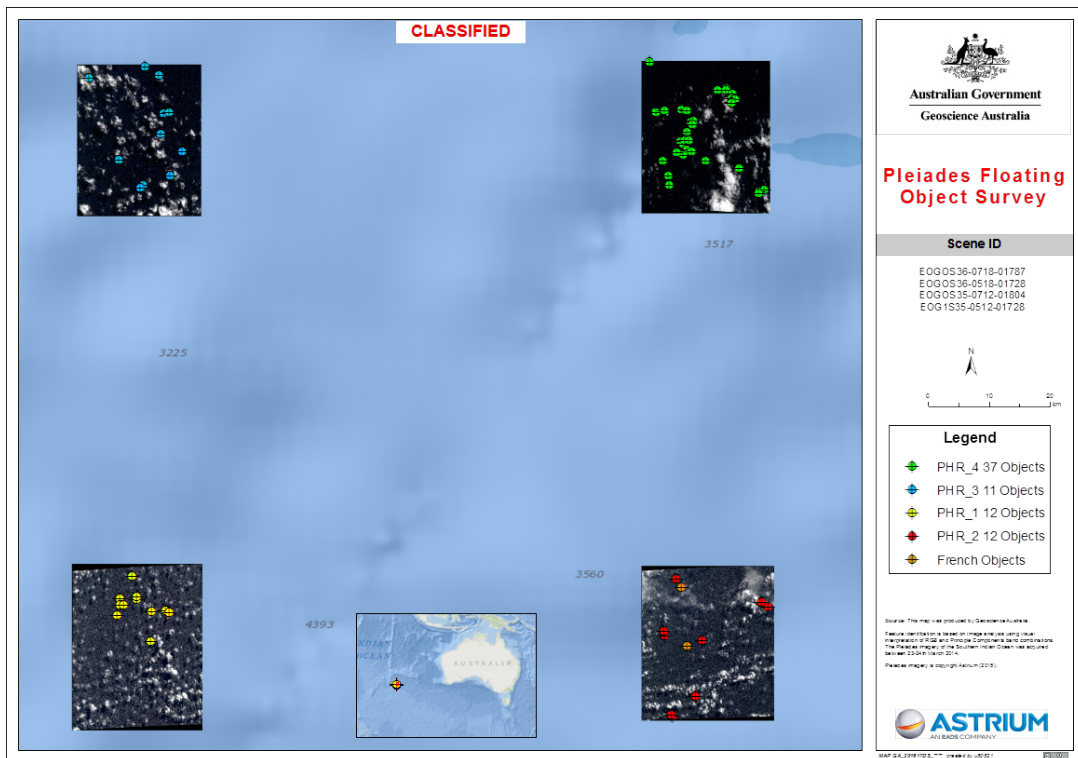


Figure 2: Overview map of all 4 supplied PLEIADES 1A (Source: French Military Intelligence Service © CNES) images over the Indian Ocean

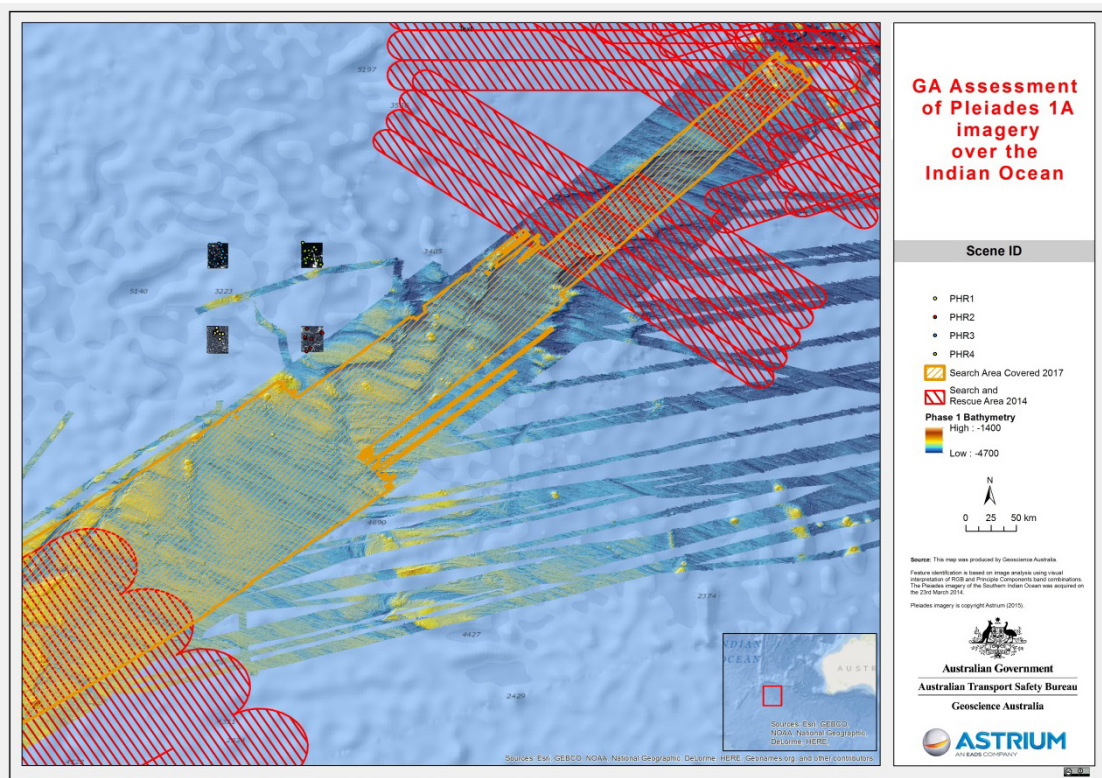


Figure 3: Close overview map of all 4 supplied PLEIADES 1A (Source: French Military Intelligence Service © CNES) images over the Indian Ocean in context of the bathymetry and underwater data acquired during the search for MH370.

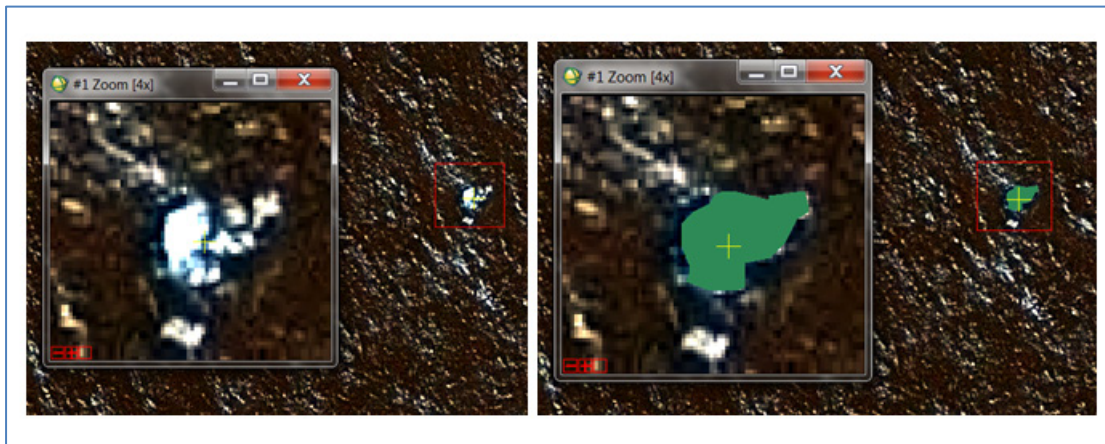


Figure 4 : Defining object extent by forming a polygon around what appears to be an irregular object: PHR_3 object 8 (Source: French Military Intelligence Service © CNES)

3.2 Image Overviews

Sections 3.2.1 to 3.2.4 display browse images of each PLEIADES 1A scene and tables of the detected objects in each. The tables provide detail on object location, size and assigned category of likely origin. Section 3.2.5 displays three of the objects detected in the PLEIADES images, to provide examples of objects that appear to be possibly man-made in origin. A complete set of images of each object is provided in the Appendix.

The objects detected in each image were:

- PHR_1 (south westerly image) - 11 objects in a clustered formation of which 1 object was classified “probably man-made”.
- PHR_2 (south easterly image) - 12 objects were found randomly scattered across the image of which 0 objects were classified “probably man-made”.
- PHR_3 (north westerly image) - 11 objects in a general east-west pattern of which 2 objects were classified “probably man-made”.
- PHR_4 (north easterly image) – 36 objects in scattered clusters across the image of which 9 objects were classified “probably man-made”.

An overall summary of the spatial distribution and density of the objects results is given in Figure 2 above.

3.2.1 PLEIADES PHR_1 image

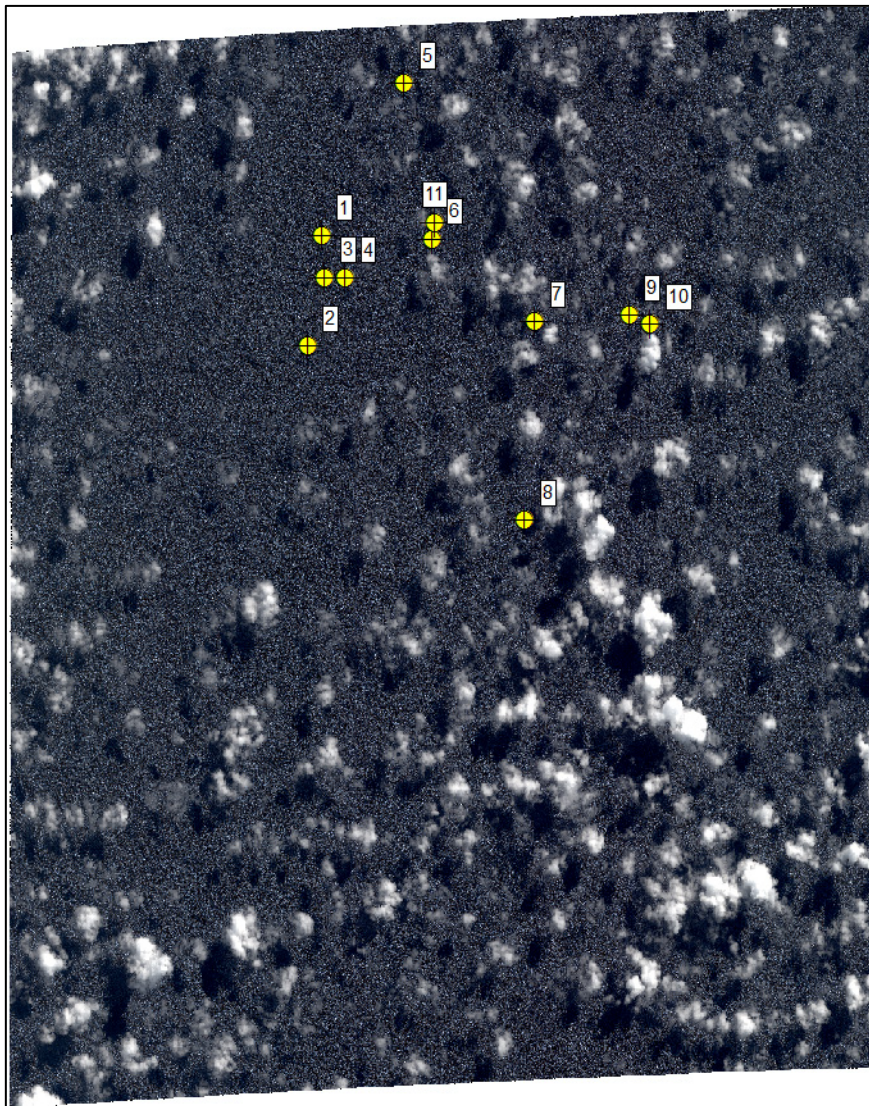


Figure 5: PHR_1 (Source: French Military Intelligence Service © CNES) browse image and surface image objects

Table 1 : PHR_1 Object locations

Point	Latitude	Longitude	# pixels	Area (m2)	Origin *
1	-35.20532	90.457967	154	39	5
2	-35.22998	90.454815	199	51	3
3	-35.21468	90.458646	179	46	4
4	-35.21476	90.463189	98	25	4
5	-35.1714	90.476377	193	49	3
6	-35.20611	90.482402	337	86	2
7	-35.22455	90.505404	254	65	2

8	-35.26884	90.503206	221	56	1
9	-35.22312	90.526393	209	53	3
10	-35.2251	90.531095	129	33	2
11	-35.20241	90.483076	207	53	3

* 1 = probably natural, 2 = possible natural, 3 = uncertain, 4 = possible man-made, 5 = probably man-made

3.2.2 PLEIADES PHR_2 image

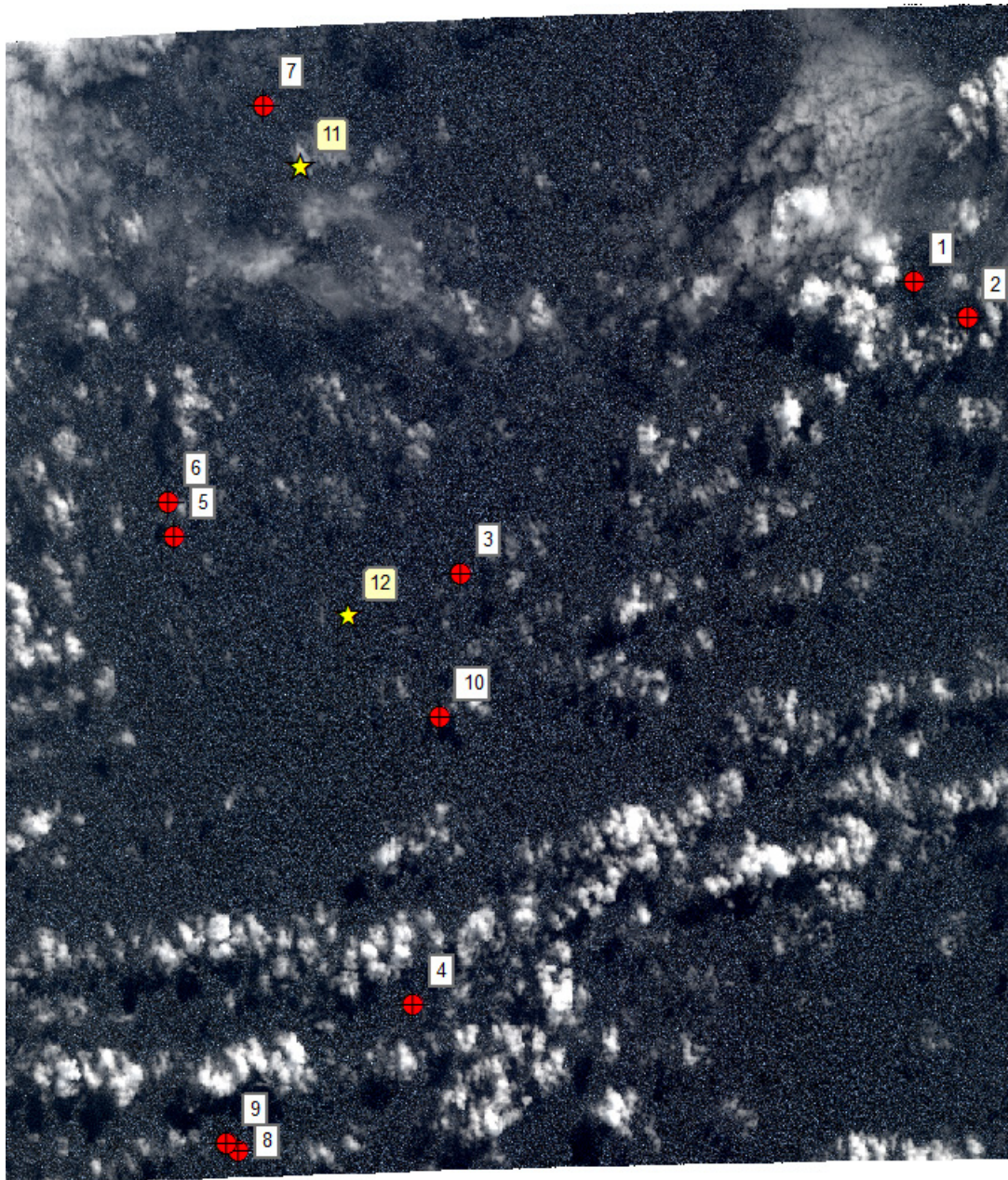


Figure 6: PHR_2 (Source: French Military Intelligence Service © CNES) browse image and surface image objects. The objects detected by both the French Ministry of Defence and Geoscience Australia are shown in yellow.

Table 2 : PHR_2 Image object locations

Point	Latitude	Longitude	# pixels	Area (m2)	Origin*
1	-35.2104	91.407116	332	85	1
2	-35.21736	91.417372	215	55	2
3	-35.26686	91.319299	131	33	4
4	-35.35032	91.310204	336	86	4
5	-35.25962	91.263932	631	162	2
6	-35.2531	91.262717	697	179	2
7	-35.17617	91.281194	581	149	3
8	-35.37856	91.27637	173	44	4
9	-35.3771	91.274066	250	64	4
10	-35.294642	91.315175	201	53	4
11^	-35.188088	91.288533	199	112	2
12^	91.29775	-35.275048	144	41	4

* 1 = probably natural, 2 = possible natural, 3 = uncertain, 4 = possible man-made, 5 = probably man-made

^ These points were also detected by the French Ministry of Defence

3.2.3 PLEIADES PHR_3 image

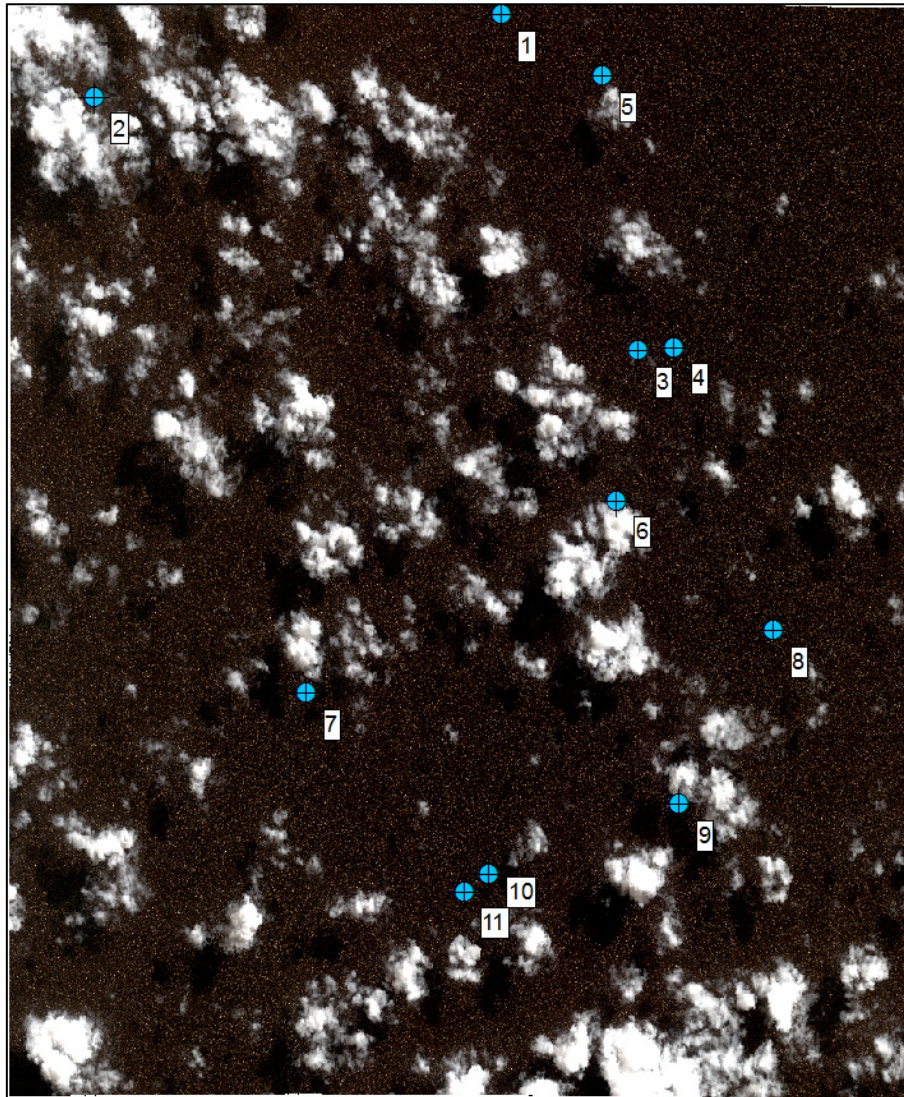


Figure 7: PHR_3 (Source: French Military Intelligence Service © CNES) browse image and surface image objects

Table 3 : PHR_3 Image object locations

Point	Latitude	Longitude	# pixels	Area (m2)	Origin
1	-34.41926	90.495984	605	153	2
2	-34.43602	90.413125	94	23	3
3	-34.48748	90.52378	181	45	2
4	-34.48684	90.531088	263	66	3
5	-34.43162	90.516533	655	165	2

6	-34.51801	90.519439	320	80	3
7	-34.55709	90.456295	241	60	5
8	-34.54434	90.55135	544	137	3
9	-34.57965	90.532203	336	85	4
10	-34.59384	90.493447	111	28	5
11	-34.59737	90.488347	178	45	3

□ * 1 = probably natural, 2 = possible natural, 3 = uncertain, 4 = possible man-made, 5 = probably man-made

3.2.4 PLEIADES PHR_4 image

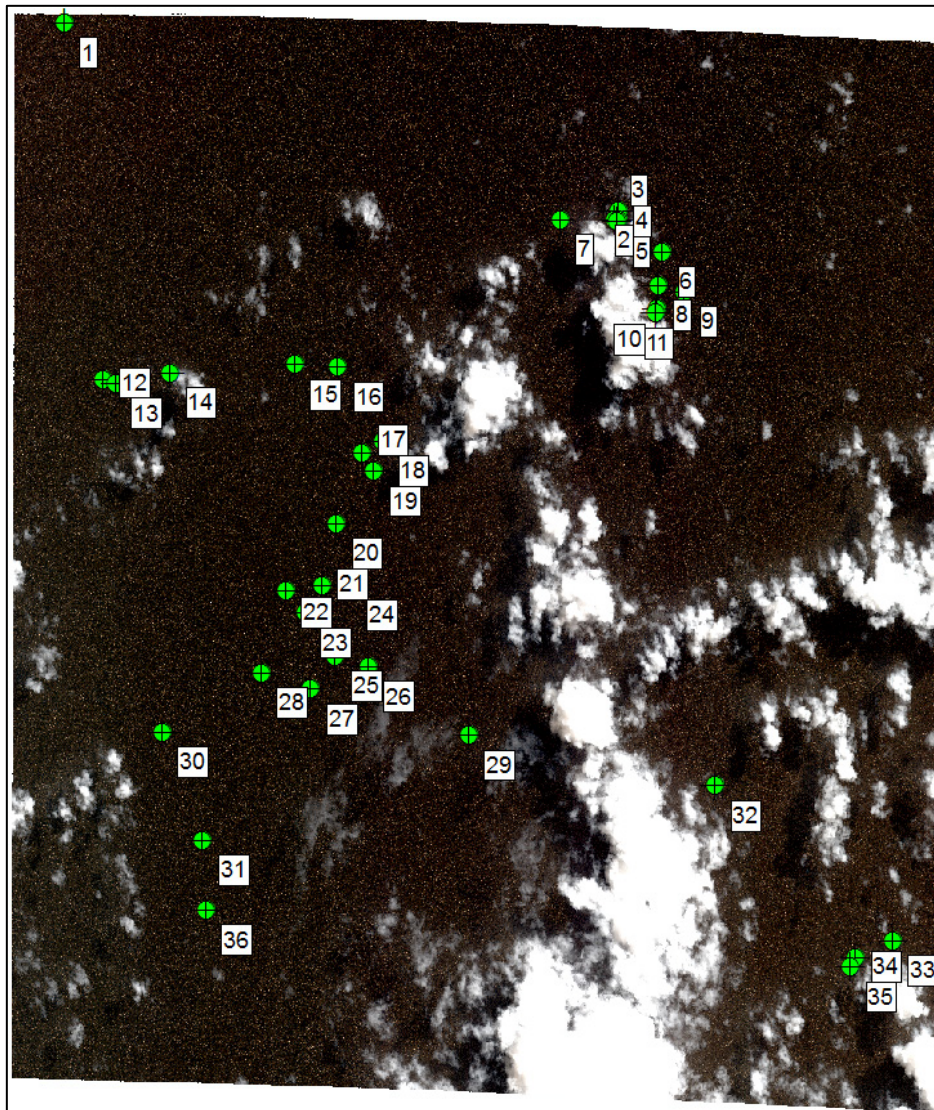


Figure 8: PHR_4 (Source: French Military Intelligence Service © CNES) browse image and surface image objects

Table 4: PHR_4 Image object locations

Point	Latitude	Longitude	# pixels	Area (m2)	Origin*
1	-34.41254	91.241808	270	68	3
2	-34.451	91.355206	277	70	5
3	-34.45289	91.354443	92	23	5
4	-34.45283	91.355169	173	43	5
5	-34.45326	91.35502	113	28	5
6	-34.45946	91.36421	100	25	5
7	-34.45285	91.343232	279	70	3
8	-34.46627	91.3633	309	78	3
9	-34.4676	91.3687	148	37	4
10	-34.47123	91.363027	208	52	4
11	-34.47199	91.362757	173	43	4
12	-34.48558	91.249819	109	27	4
13	-34.48637	91.252249	191	48	2
14	-34.48424	91.263481	98	24	3
15	-34.4825	91.288974	168	42	4
16	-34.48299	91.2978	145	36	4
17	-34.50069	91.3028	125	31	4
18	-34.49835	91.30698	274	69	5
19	-34.50437	91.305206	165	41	5
20	-34.51518	91.29748	117	29	3
21	-34.52787	91.294457	314	79	3
22	-34.5288	91.287157	298	75	2
23	-34.53335	91.291068	170	43	3
24	-34.52764	91.300619	138	34	4
25	-34.5422	91.297322	375	94	4
26	-34.54438	91.304036	196	49	5
27	-34.54901	91.292308	157	39	5
28	-34.54569	91.282163	102	25	4
29	-34.55841	91.324571	184	38	4
30	-34.55782	91.261753	184	46	4
31	-34.57997	91.270134	137	34	4

32	-34.56875	91.375018	177	44	4
33	-34.60054	91.411363	246	62	4
34	-34.60402	91.403769	90	22	4
35	-34.60588	91.402719	208	52	4
36	-34.59424	91.270729	72	18	4

* 1 = probably natural, 2 = possible natural, 3 = uncertain, 4 = possible man-made, 5 = probably man-made

3.2.5 Probable man-made objects

The following images illustrate the twelve objects detected that we assessed to be “probably man-made” in origin. The objects show geometric shapes that do not conform with wave patterns, or other expected natural phenomena, and are different in character to their surroundings.

In each of the paired images below, the left hand image is the ‘natural colour’, whereas the right hand image has been enhanced using PCA. The colours of the enhanced image are not significant, serving only to provide contrast. The background image shows the object in a wider context (the location of the object is indicated by a red square).

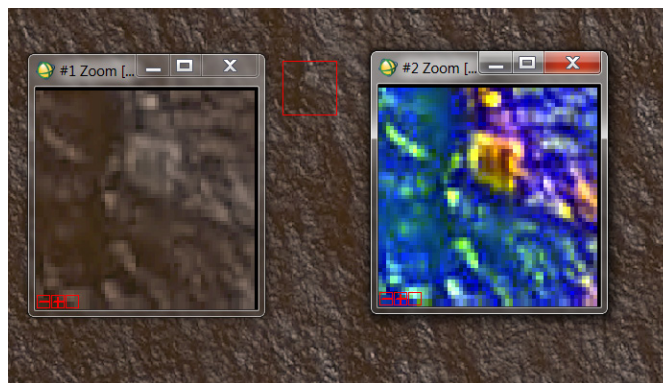


Figure 9: PHR_1 Image object 1 (Source: French Military Intelligence Service © CNES)

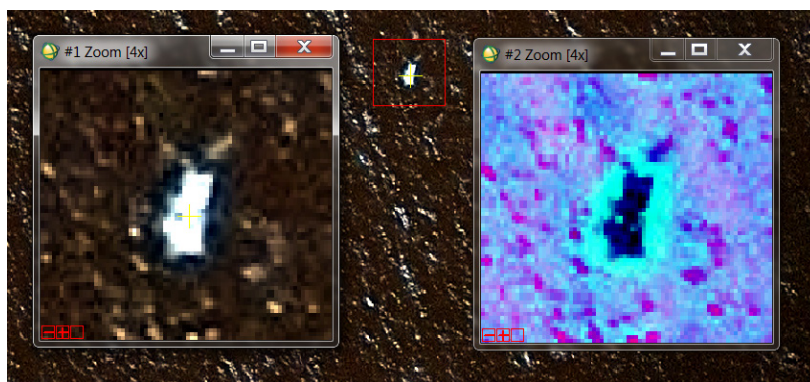


Figure 10: PHR_3 Image object 7 (Source: French Military Intelligence Service © CNES)

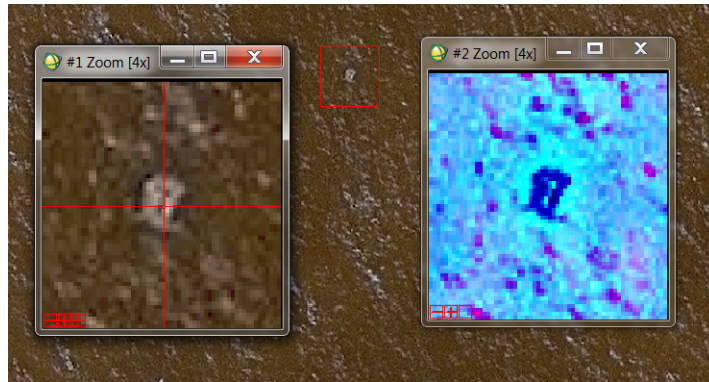


Figure 11: PHR_3 Image object 10 (Source: French Military Intelligence Service © CNES)

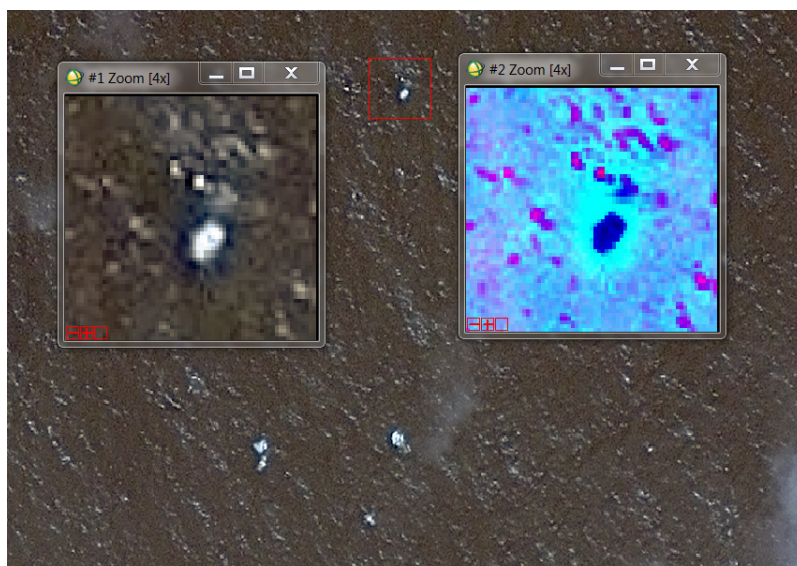


Figure 12: PHR_4 Image object 2 (Source: French Military Intelligence Service © CNES)

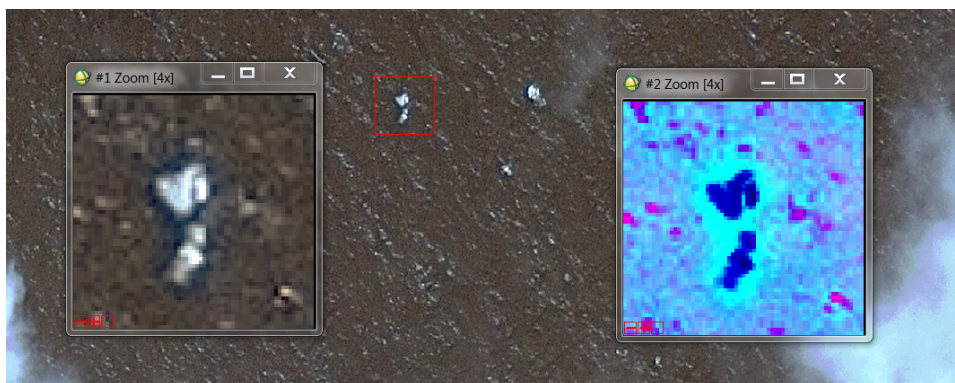


Figure 13: PHR_4 Image object 3 (Source: French Military Intelligence Service © CNES)



Figure 14: PHR_4 Image object 4 (Source: French Military Intelligence Service © CNES)

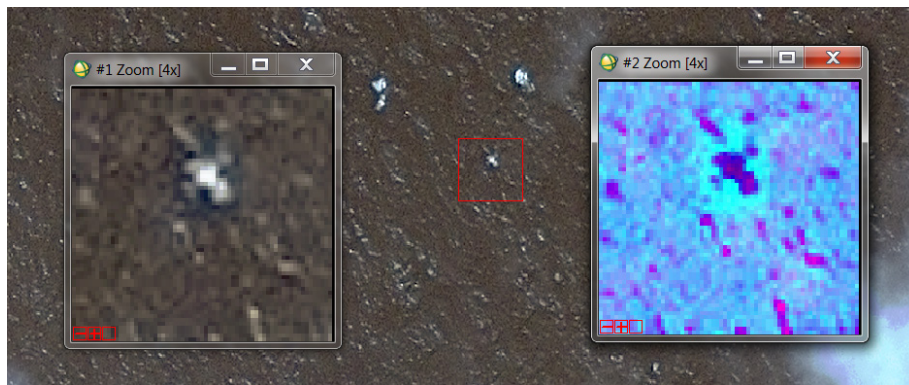


Figure 15: PHR_4 Image object 5 (Source: French Military Intelligence Service © CNES)

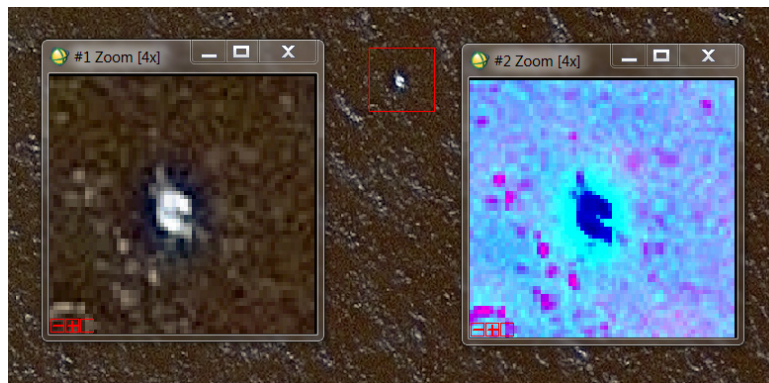


Figure 16: PHR_4 Image object 6 (Source: French Military Intelligence Service © CNES)

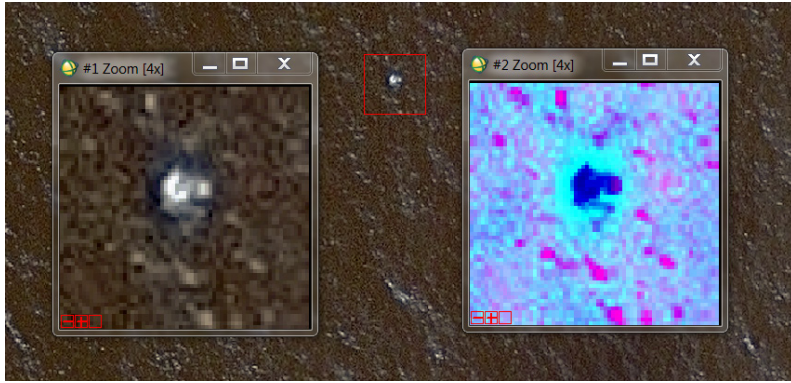


Figure 17: PHR_4 Image object 18 (Source: French Military Intelligence Service © CNES)

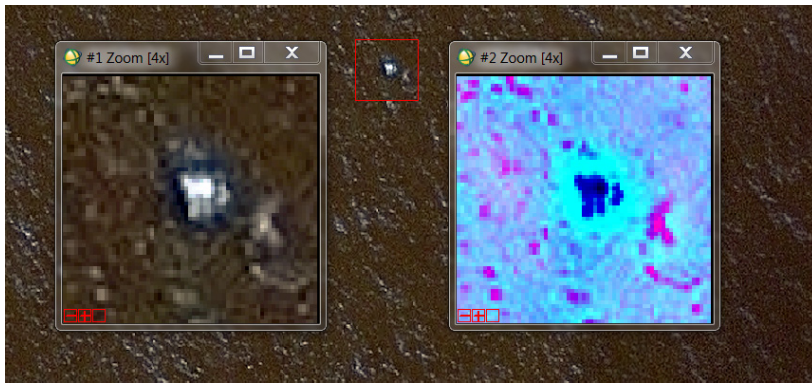


Figure 18: PHR_4 Image object 19 (Source: French Military Intelligence Service © CNES)

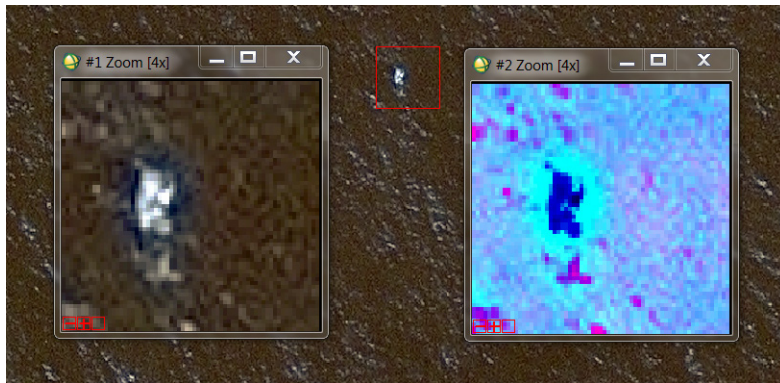


Figure 19: PHR_4 Image object 26 (Source: French Military Intelligence Service © CNES)

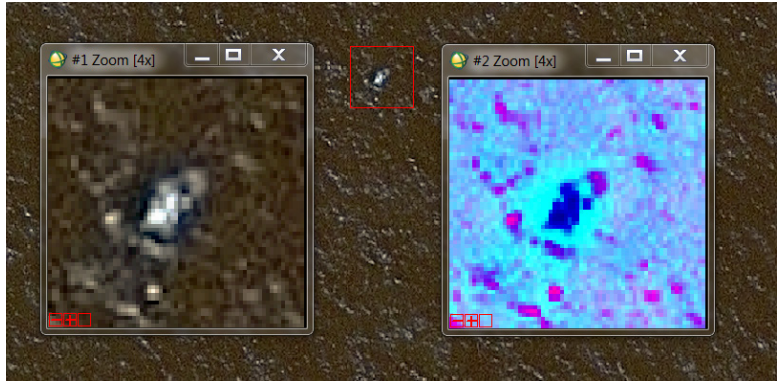


Figure 20: PHR_4 Image object 27 (Source: French Military Intelligence Service © CNES)

4 Conclusion

The GA analysis of the four PLEIADES 1A images supplied by ATSB was conducted using visual interpretation aided by a Principal Components Analysis to help highlight objects against the surrounding areas.

The analysis classified 12 objects as “probably man-made”, from a total of 70 detected objects. Each object was categorised in one of five classes of likelihood of being man-made in origin.

The majority (36 of 70) of all detected objects were found in the north-easterly image (PHR_4). PHR_4 also contained 9 of the 12 objects classified as “probably man made”.

This analysis indicates a probable cluster of man-made objects in the north-easterly image (PHR_4) on March 23 2014 but cannot determine whether they are aircraft debris.

5 Appendix

This appendix provides images of each detected object in true colour plus the associated PCA image. It also provides representative spectra found in each PLEIADES 1A image.

5.1.1 Objects detected in PHR_1

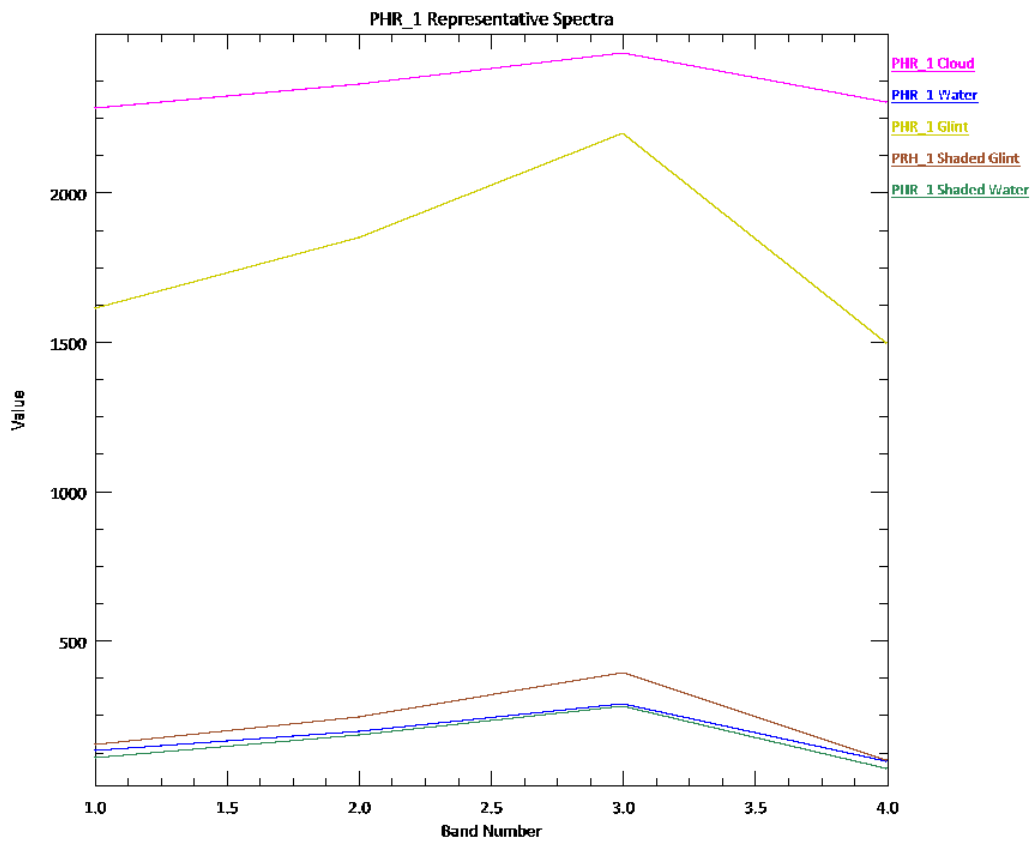


Figure 21: PHR_1 Representative Spectra

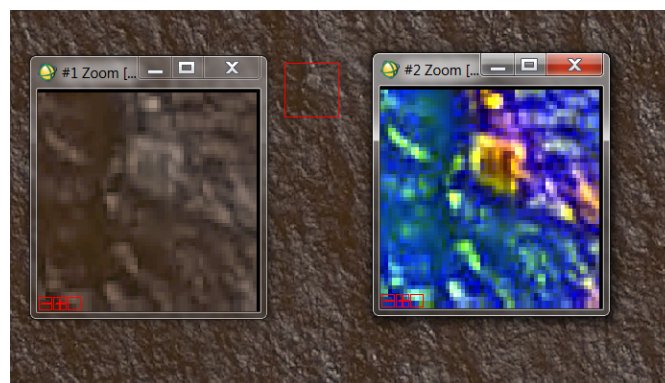


Figure 22: PHR_1 Image object 1 (Source: French Military Intelligence Service © CNES)

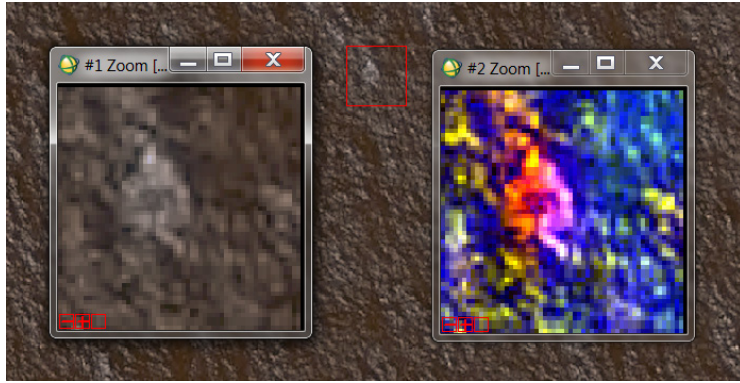


Figure 23: PHR_1 Image object 2 (Source: French Military Intelligence Service © CNES)



Figure 24: PHR_1 Image object 3 (Source: French Military Intelligence Service © CNES)

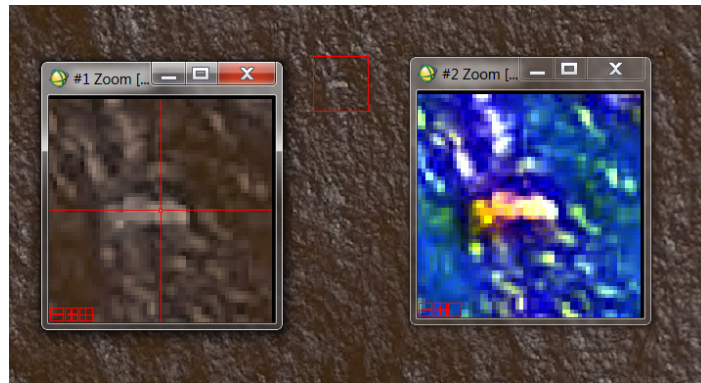


Figure 25: PHR_1 Image object 4 (Source: French Military Intelligence Service © CNES)



Figure 26: PHR_1 Image object 5 (Source: French Military Intelligence Service © CNES)

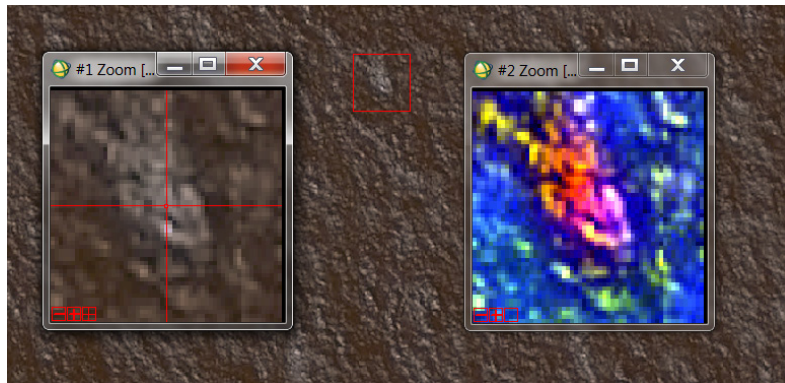


Figure 27: PHR_1 Image object 6 (Source: French Military Intelligence Service © CNES)



Figure 28: PHR_1 Image object 7 (Source: French Military Intelligence Service © CNES)



Figure 29: PHR_1 Image object 8 (Source: French Military Intelligence Service © CNES)

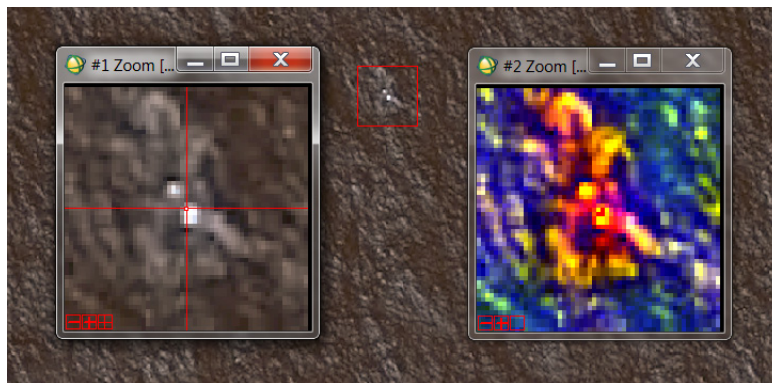


Figure 30: PHR_1 Image object 9 (Source: French Military Intelligence Service © CNES)



Figure 31: PHR_1 Image object 10 (Source: French Military Intelligence Service © CNES)



Figure 32: PHR_1 Image object 11 (Source: French Military Intelligence Service © CNES)

5.1.2 Objects detected in PHR_2

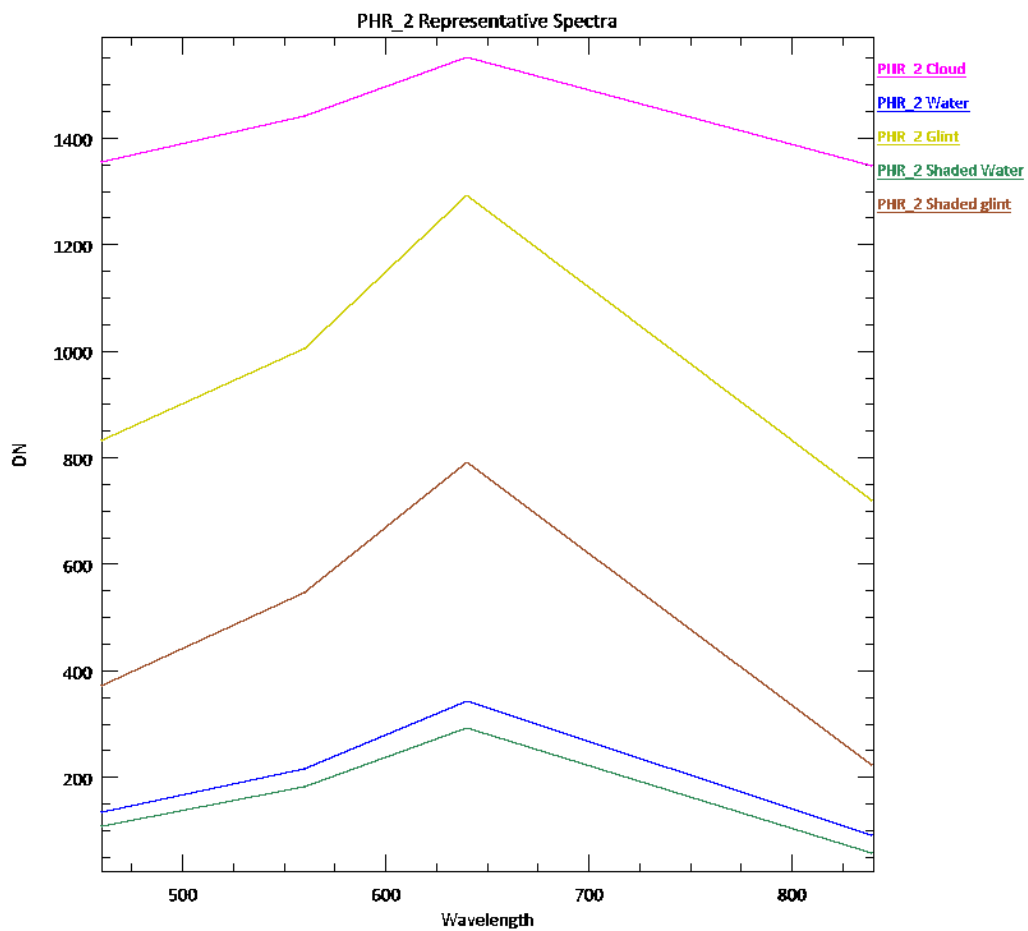


Figure 33: PHR_2 Representative spectra

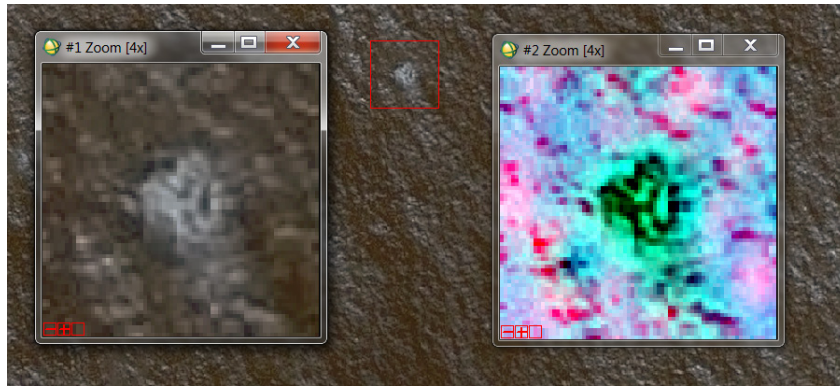


Figure 34: PHR_2 Image object 1 (Source: French Military Intelligence Service © CNES)

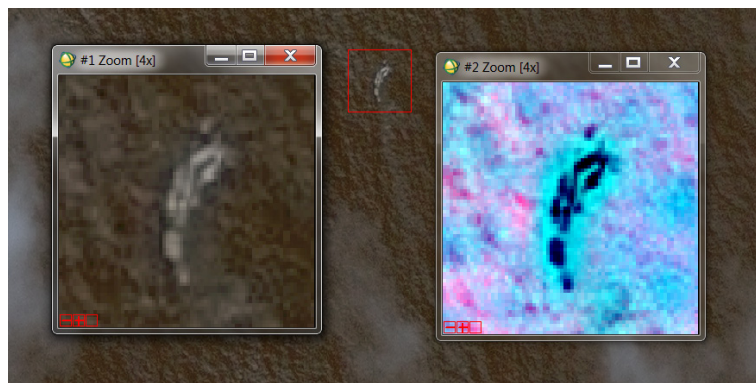


Figure 35: PHR_2 Image object 2 (Source: French Military Intelligence Service © CNES)

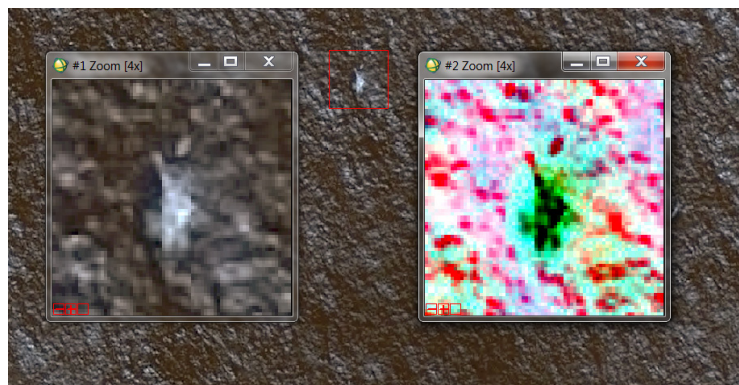


Figure 36: PHR_2 Image object 3 (Source: French Military Intelligence Service © CNES)

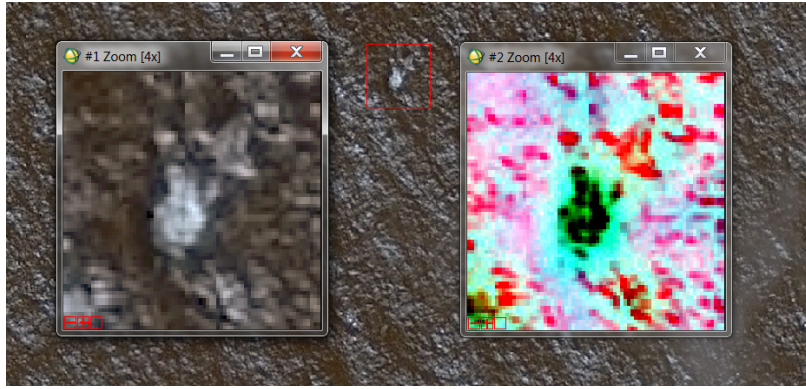


Figure 37: PHR_2 Image object 4 (Source: French Military Intelligence Service © CNES)

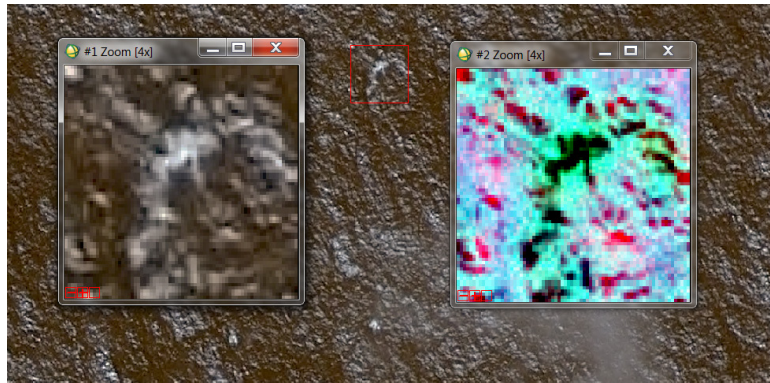


Figure 38: PHR_2 Image object 5 (Source: French Military Intelligence Service © CNES)

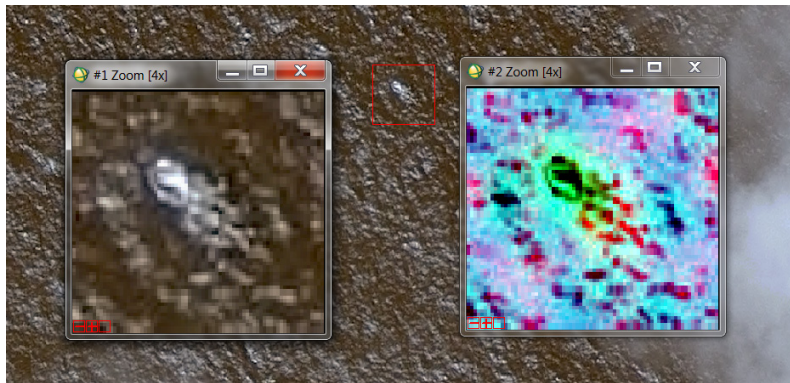


Figure 39: PHR_2 Image object 6 (Source: French Military Intelligence Service © CNES)

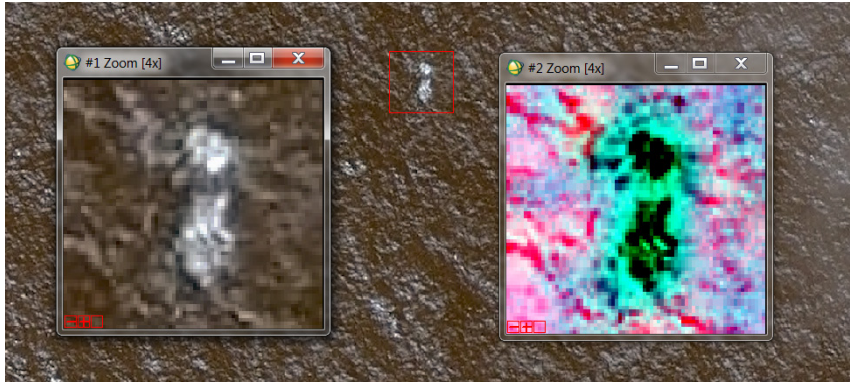


Figure 40: PHR_2 Image object 7 (Source: French Military Intelligence Service © CNES)

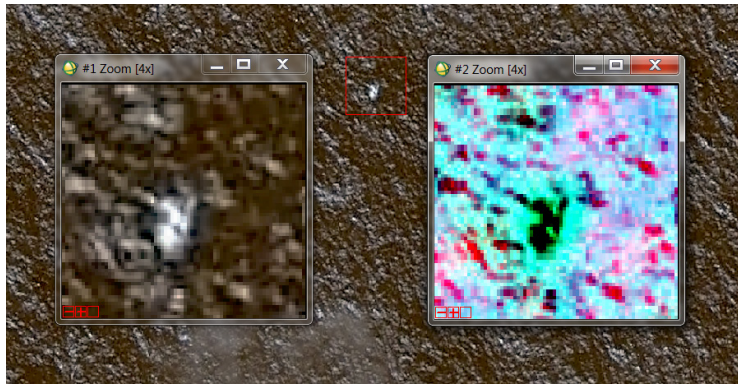


Figure 41: PHR_2 Image object 8 (Source: French Military Intelligence Service © CNES)

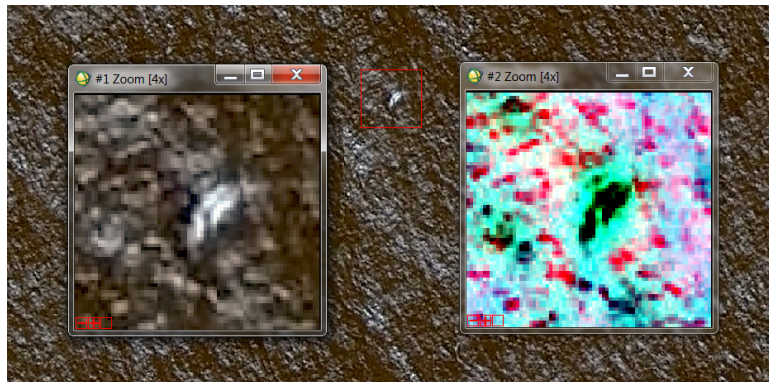


Figure 42: PHR_2 Image object 9 (Source: French Military Intelligence Service © CNES)

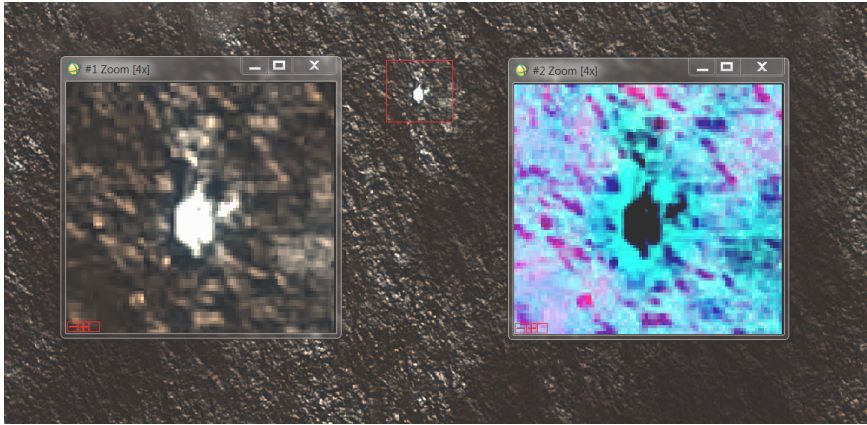


Figure 43: PHR_2 Image object 10 (Source: French Military Intelligence Service © CNES)

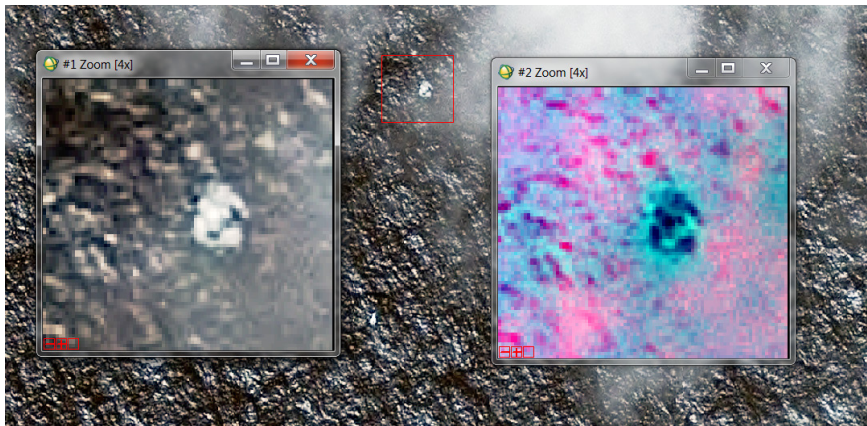


Figure 44: PHR_2 Image object 11 (Source: French Military Intelligence Service © CNES)

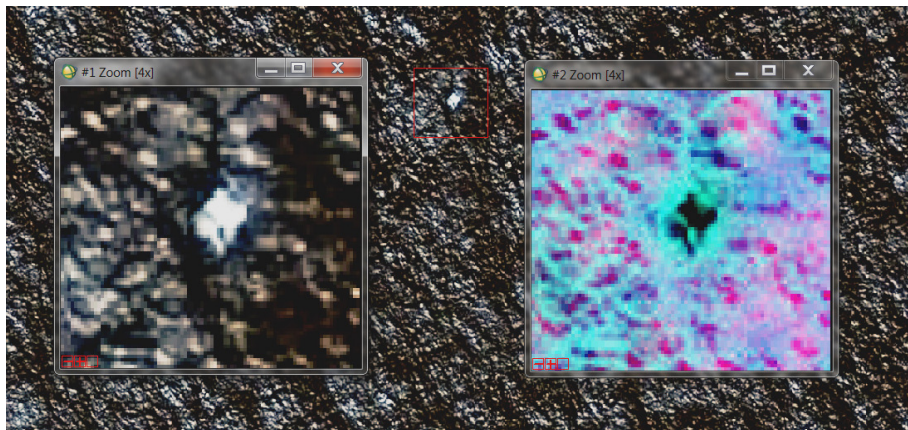


Figure 45: PHR_2 Image object 12 (Source: French Military Intelligence Service © CNES)

5.1.3 Objects detected in PHR_3

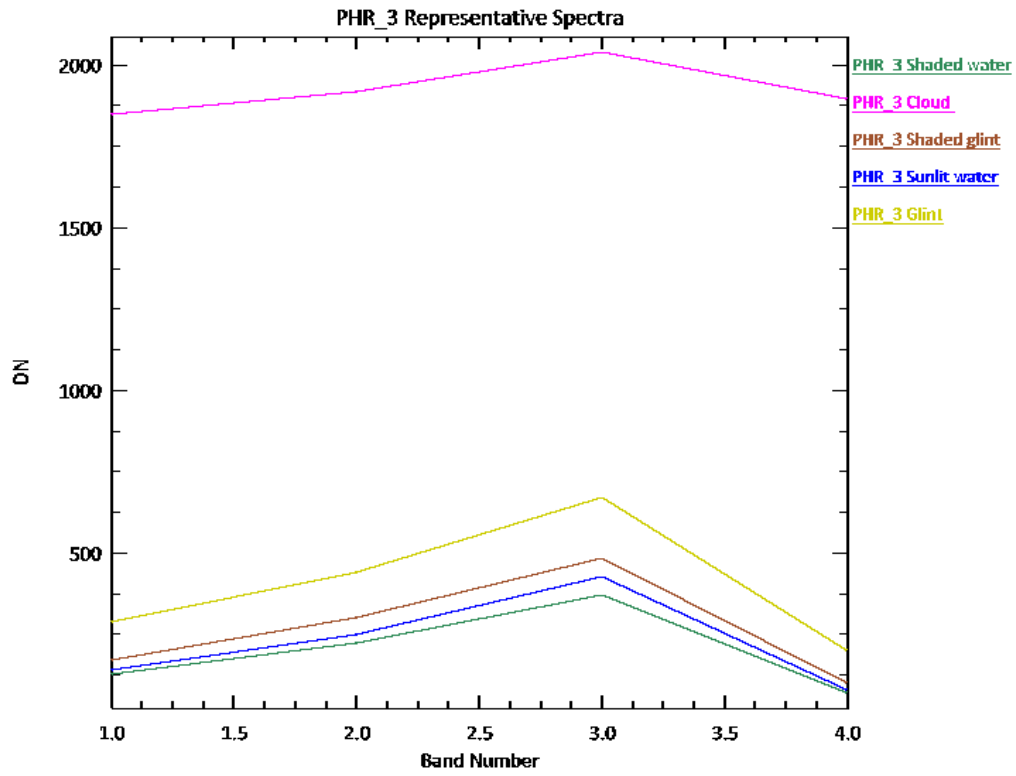


Figure 46: PHR_3 Representative spectra

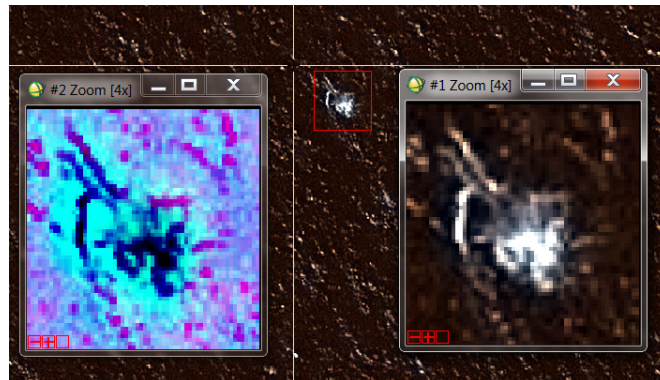


Figure 47: PHR_3 Image object 1 (Source: French Military Intelligence Service © CNES)

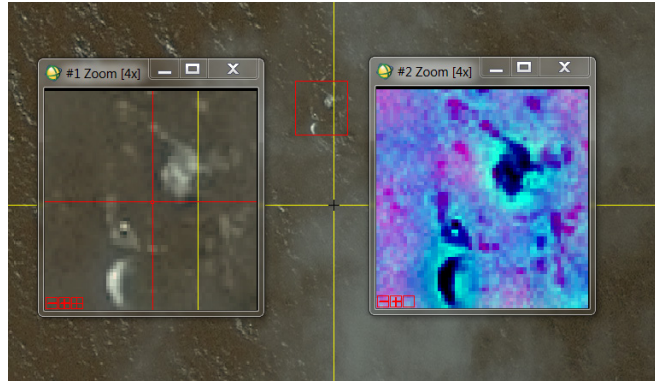


Figure 48: PHR_3 Image object 2 (Source: French Military Intelligence Service © CNES)

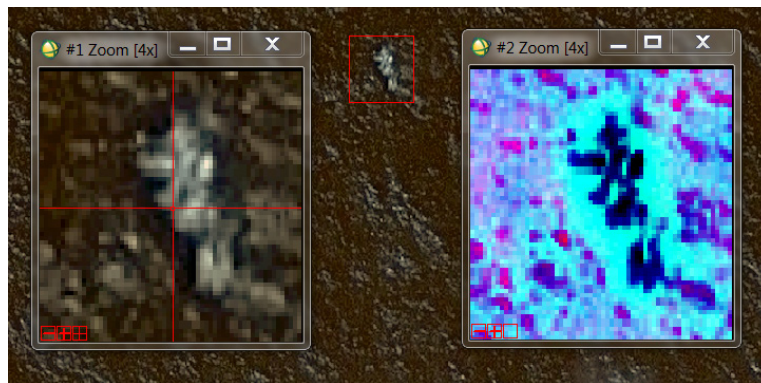


Figure 49: PHR_3 Image object 3 (Source: French Military Intelligence Service © CNES)

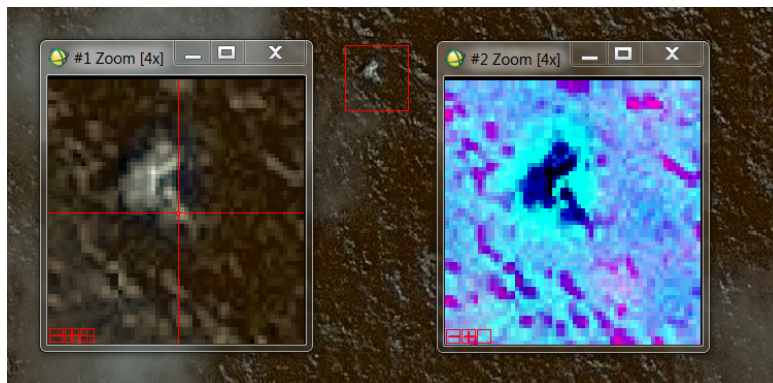


Figure 50: PHR_3 Image object 4 (Source: French Military Intelligence Service © CNES)

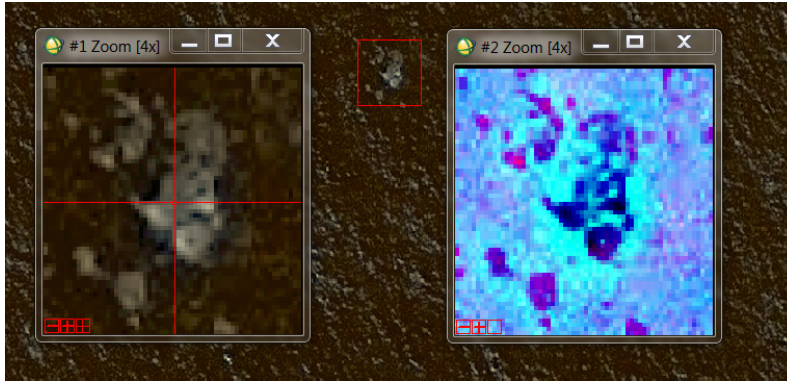


Figure 51: PHR_3 Image object 5 (Source: French Military Intelligence Service © CNES)

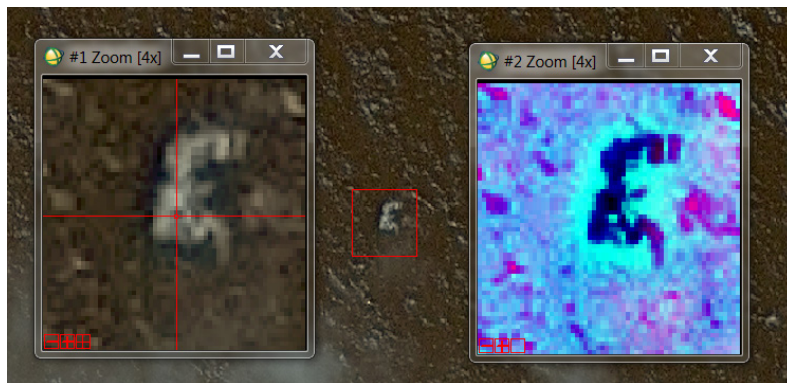


Figure 52: PHR_3 Image object 6 (Source: French Military Intelligence Service © CNES)

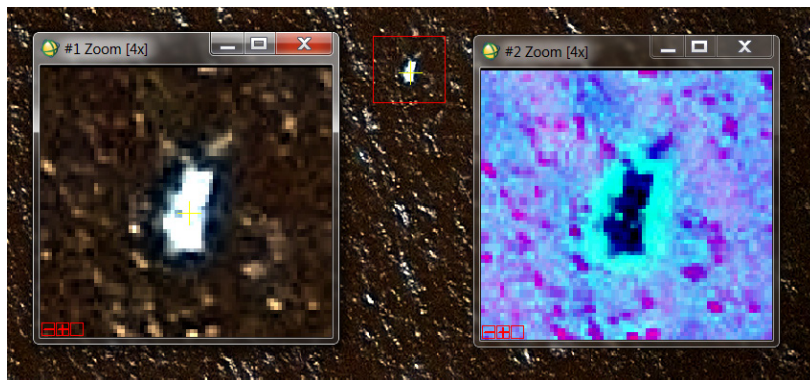


Figure 53: PHR_3 object 7 (Source: French Military Intelligence Service © CNES)

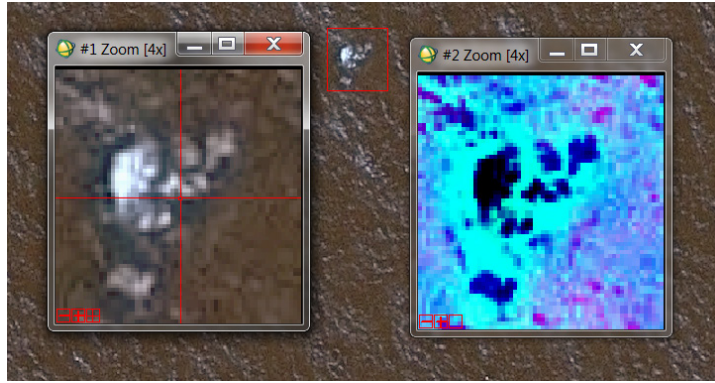


Figure 54: PHR_3 Image object 8 (Source: French Military Intelligence Service © CNES)

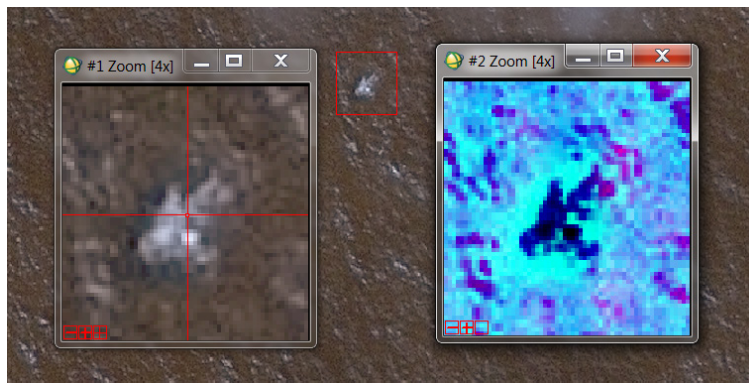


Figure 55: PHR_3 Image object 9 (Source: French Military Intelligence Service © CNES)

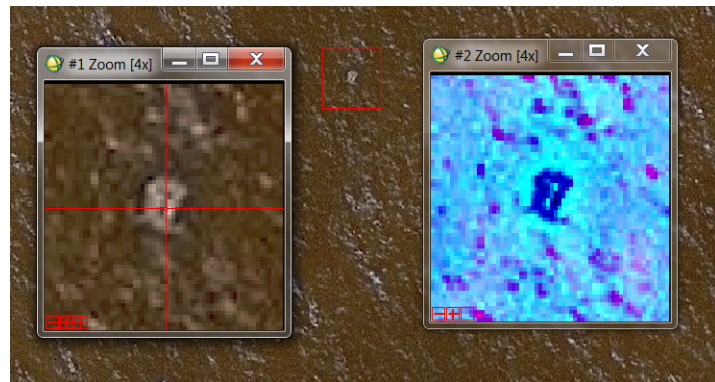


Figure 56: PHR_3 Image object 10 (Source: French Military Intelligence Service © CNES)

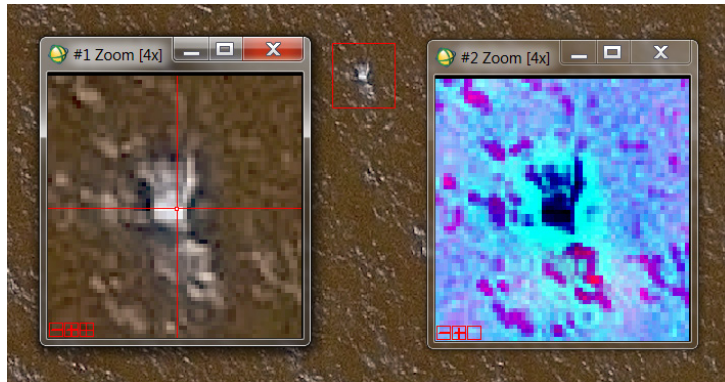


Figure 57: PHR_3 Image object 11 (Source: French Military Intelligence Service © CNES)

5.1.4 Objects detected in PHR_4

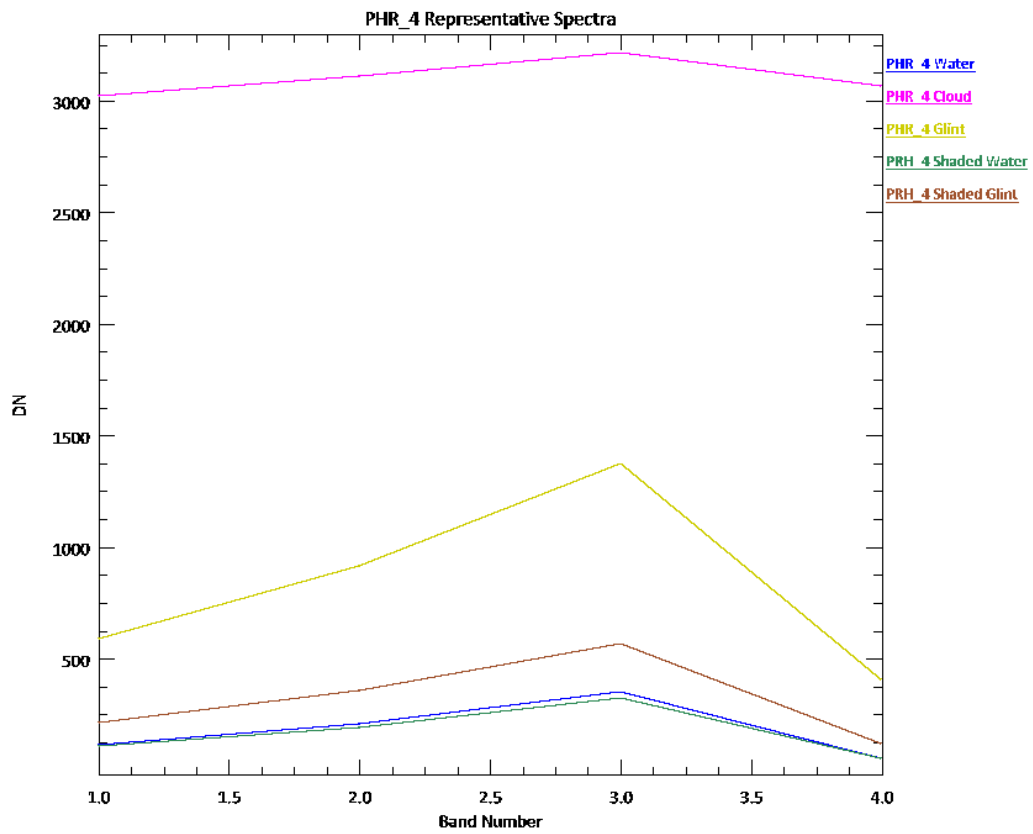


Figure 58: PHR_4 Representative Spectra

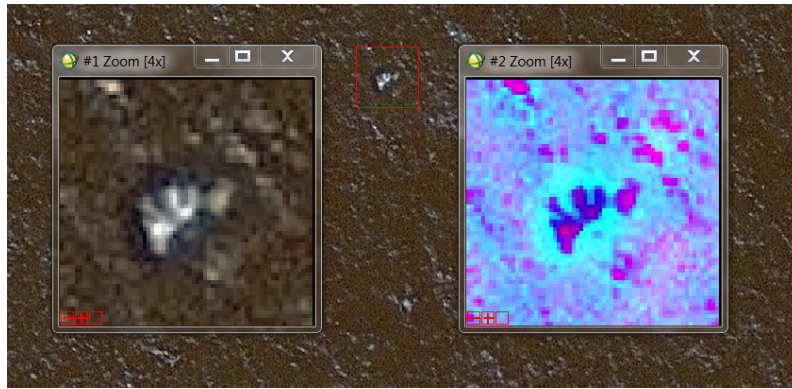


Figure 59: PHR_4 Image object 1 (Source: French Military Intelligence Service © CNES)

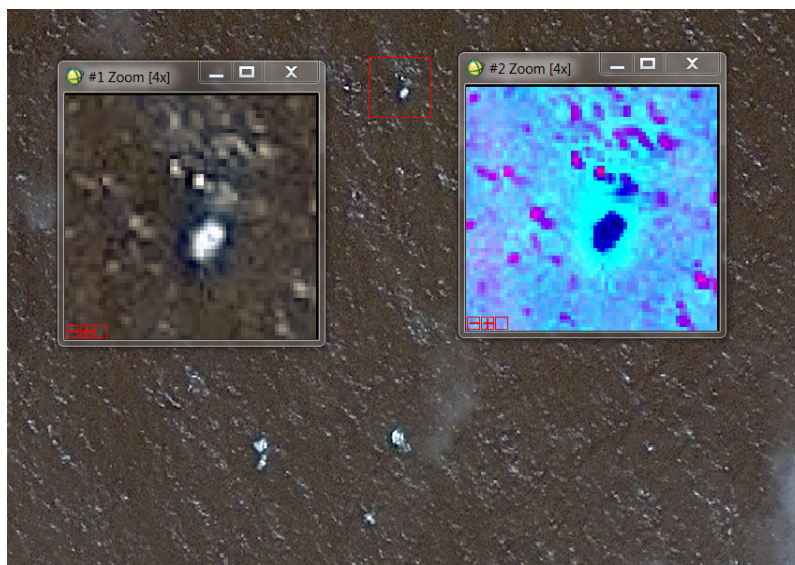


Figure 60: PHR_4 Image object 2 (Source: French Military Intelligence Service © CNES)



Figure 61: PHR_4 Image object 3 (Source: French Military Intelligence Service © CNES)



Figure 62: PHR_4 Image object 4 (Source: French Military Intelligence Service © CNES)

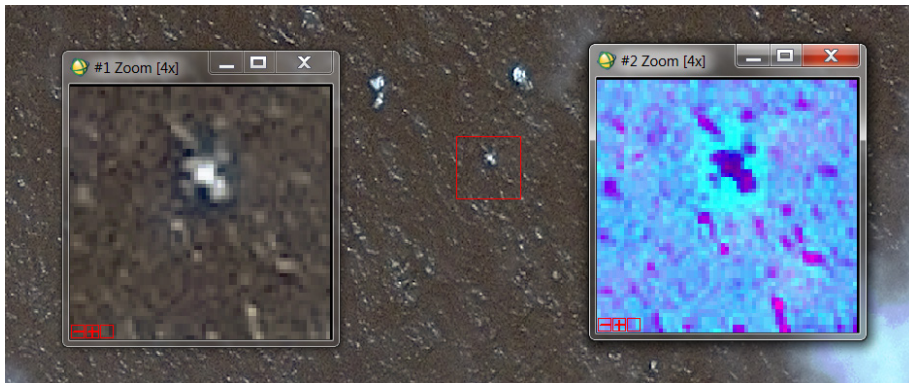


Figure 63: PHR_4 Image object 5 (Source: French Military Intelligence Service © CNES)

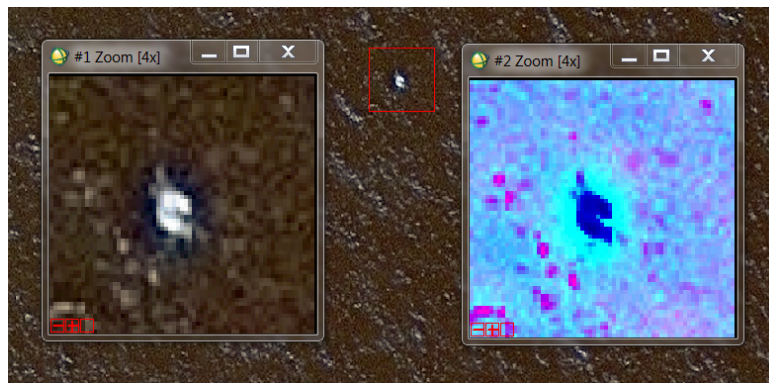


Figure 64: PHR_4 Image object 6 (Source: French Military Intelligence Service © CNES)

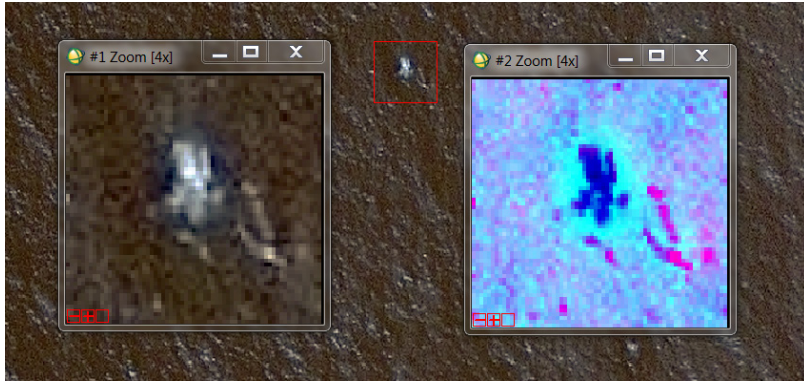


Figure 65: PHR_4 Image object 7 (Source: French Military Intelligence Service © CNES)

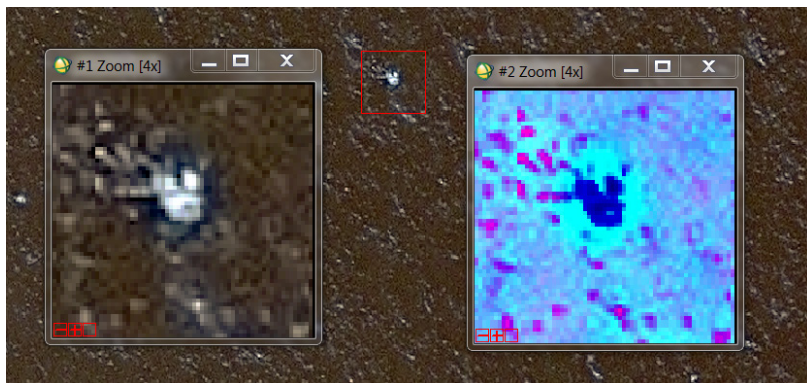


Figure 66: PHR_4 Image object 8 (Source: French Military Intelligence Service © CNES)

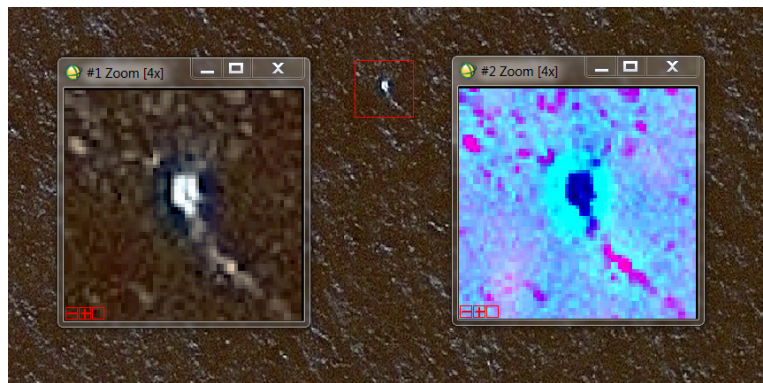


Figure 67: PHR_4 Image object 9 (Source: French Military Intelligence Service © CNES)

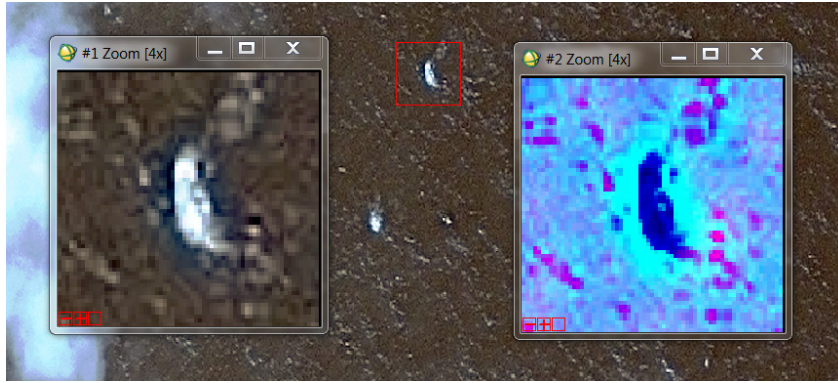


Figure 68: PHR_4 Image objects 10 (Source: French Military Intelligence Service © CNES)

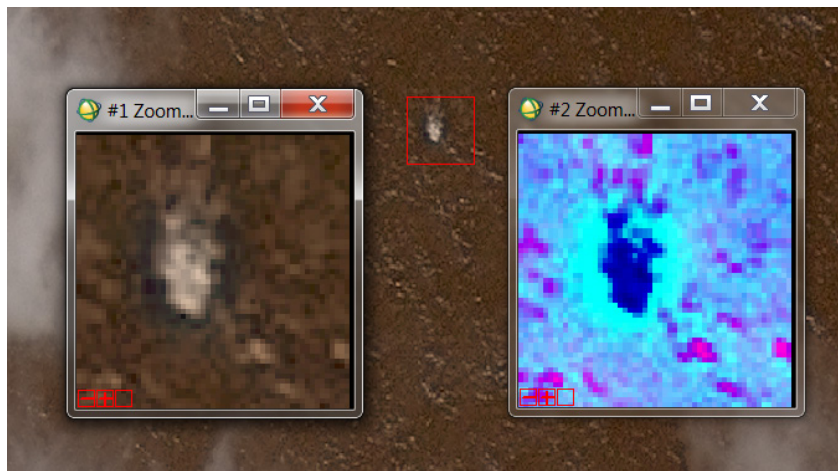


Figure 69: PHR_4 Image object 11 (Source: French Military Intelligence Service © CNES)



Figure 70: PHR_4 Image object 12 (Source: French Military Intelligence Service © CNES)



Figure 71: PHR_4 Image object 13 (Source: French Military Intelligence Service © CNES)



Figure 72: PHR_4 Image object 14 (Source: French Military Intelligence Service © CNES)

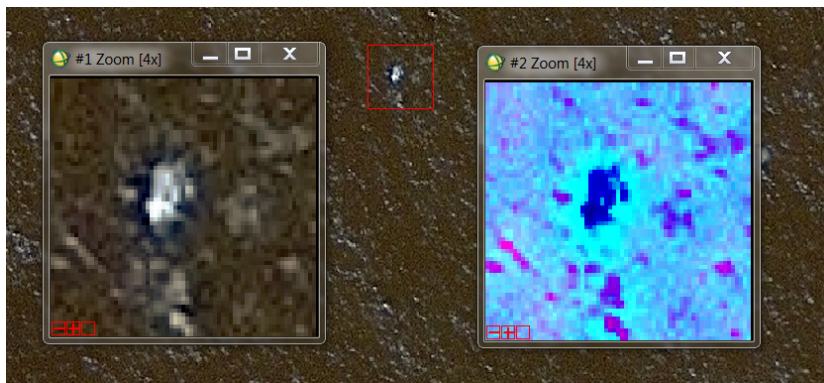


Figure 73: PHR_4 Image object 15 (Source: French Military Intelligence Service © CNES)

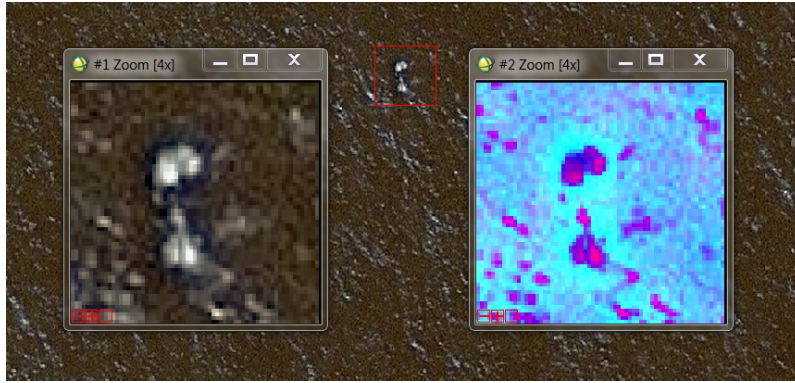


Figure 74: PHR_4 Image object 16 (Source: French Military Intelligence Service © CNES)

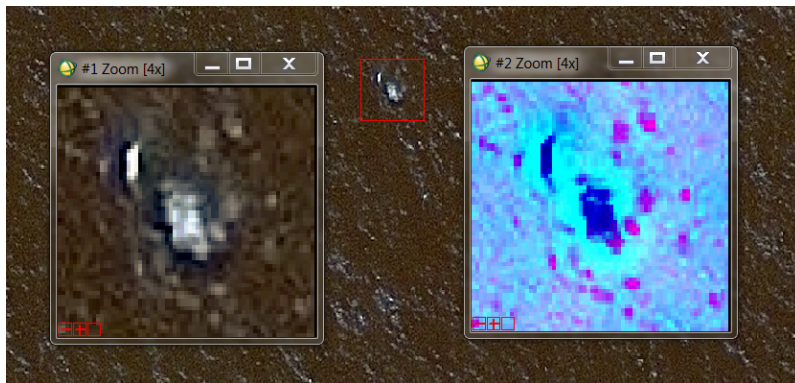


Figure 75: PHR_4 Image object 17 (Source: French Military Intelligence Service © CNES)

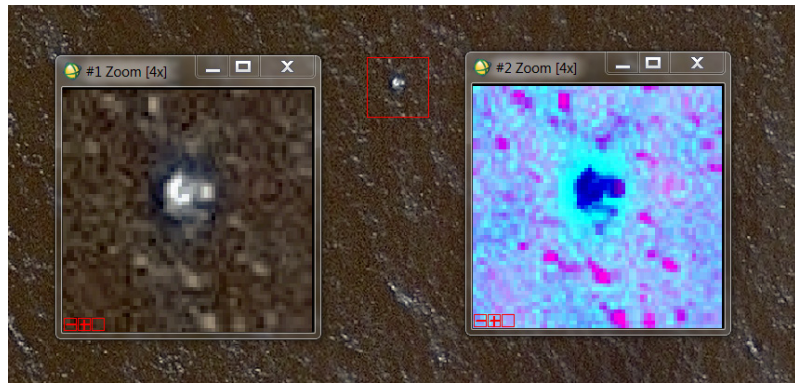


Figure 76: PHR_4 Image object 18 (Source: French Military Intelligence Service © CNES)

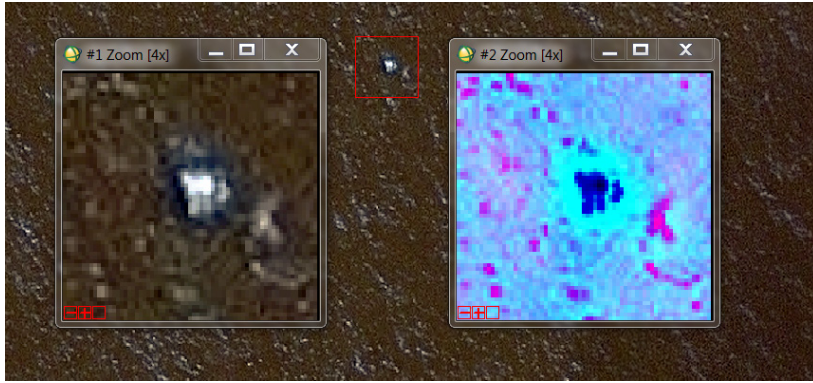


Figure 77: PHR_4 Image object 19 (Source: French Military Intelligence Service © CNES)

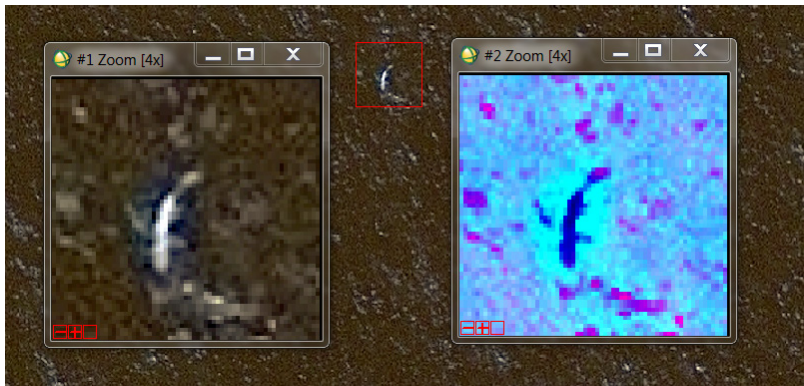


Figure 78: PHR_4 Image object 20 (Source: French Military Intelligence Service © CNES)

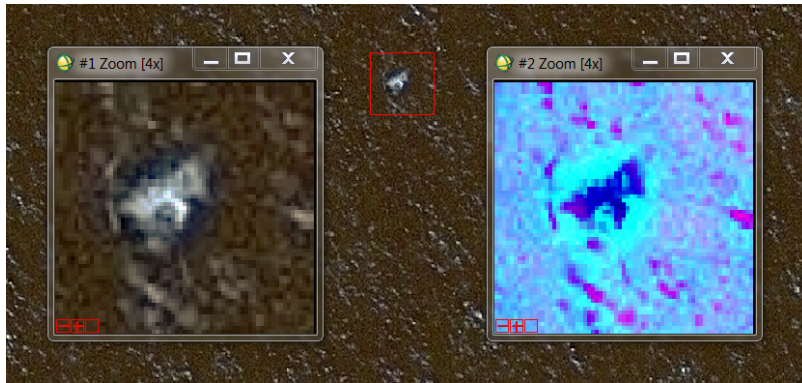


Figure 79: PHR_4 Image object 21 (Source: French Military Intelligence Service © CNES)

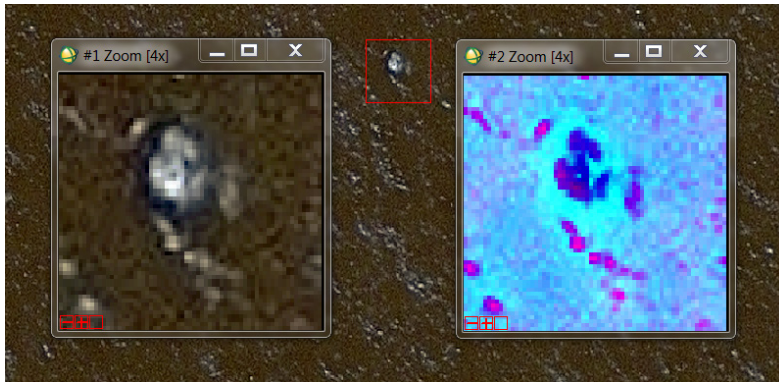


Figure 80: PHR_4 Image object 22 (Source: French Military Intelligence Service © CNES)

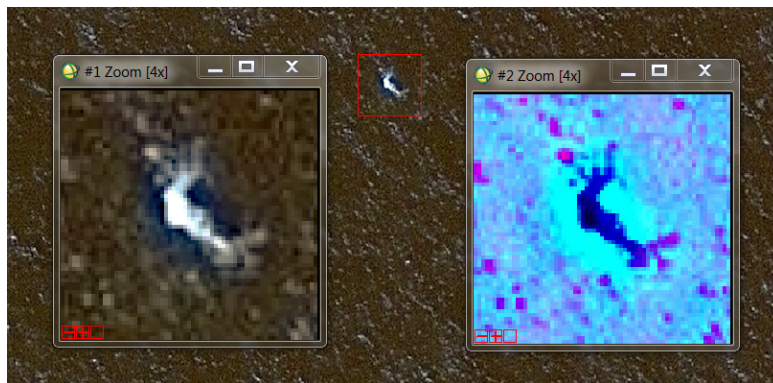


Figure 81: PHR_4 Image object 23 (Source: French Military Intelligence Service © CNES)

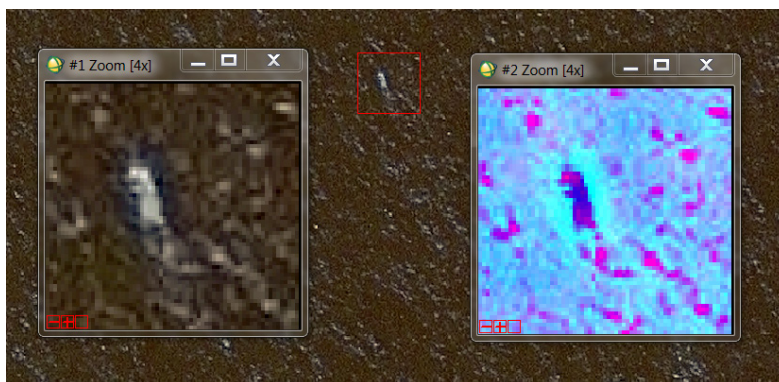


Figure 82: PHR_4 Image object 24 (Source: French Military Intelligence Service © CNES)

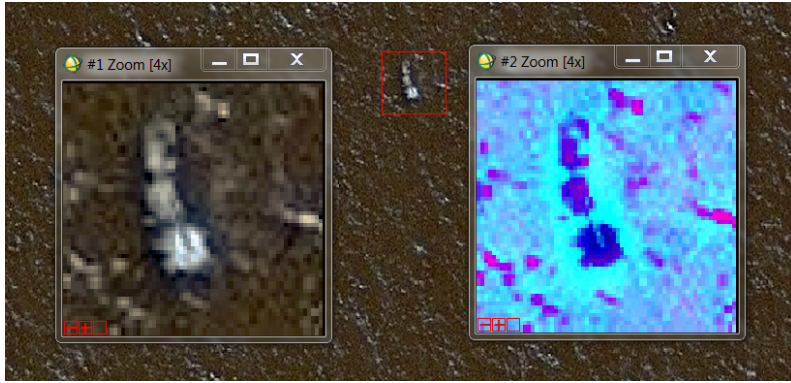


Figure 83: PHR_4 Image object 25 (Source: French Military Intelligence Service © CNES)

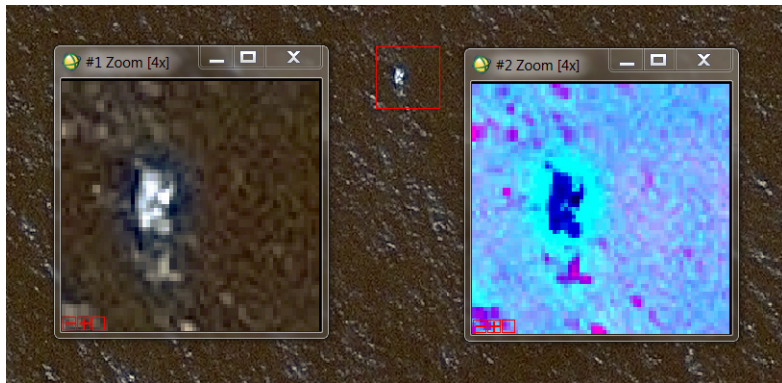


Figure 84: PHR_4 Image object 26 (Source: French Military Intelligence Service © CNES)

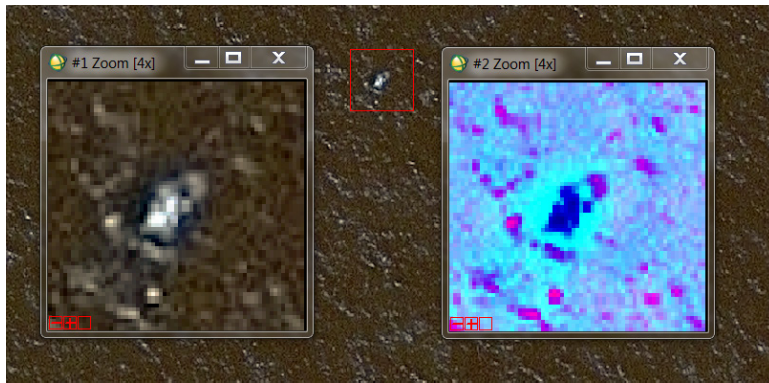


Figure 85: PHR_4 Image object 27 (Source: French Military Intelligence Service © CNES)

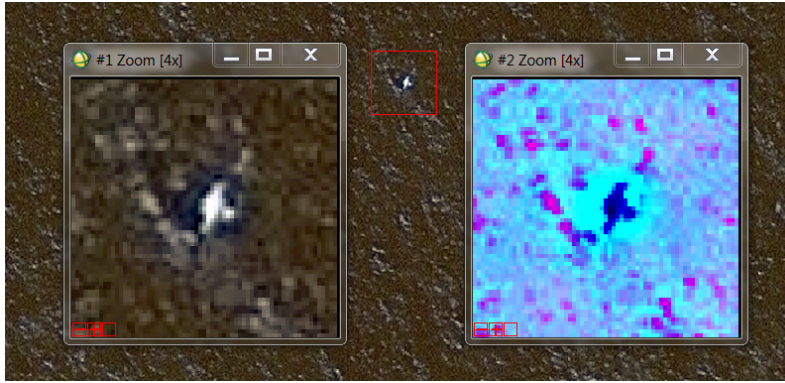


Figure 86: PHR_4 Image object 28 (Source: French Military Intelligence Service © CNES)

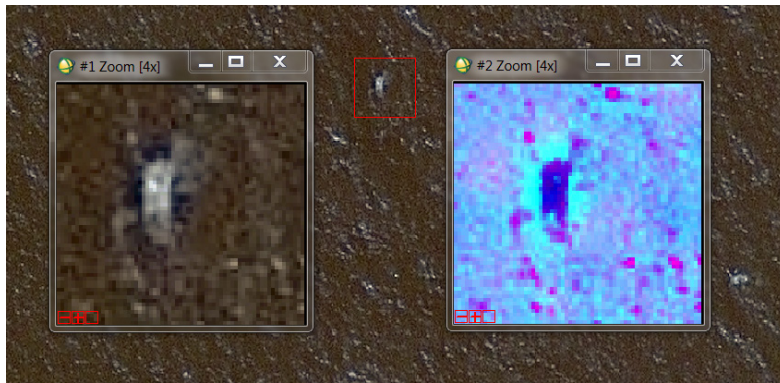


Figure 87: PHR_4 Image object 29 (Source: French Military Intelligence Service © CNES)

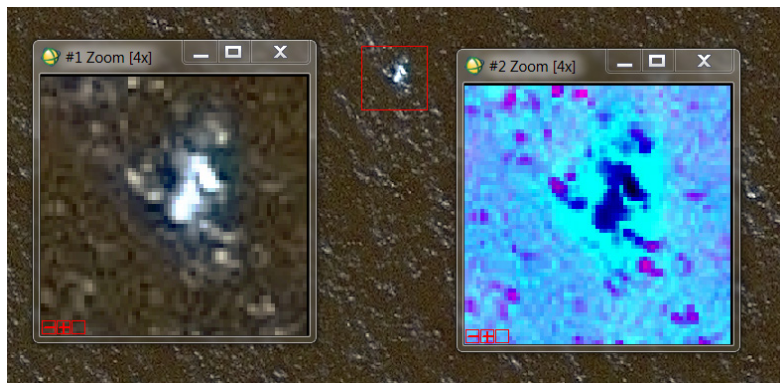


Figure 88: PHR_4 Image object 30 (Source: French Military Intelligence Service © CNES)

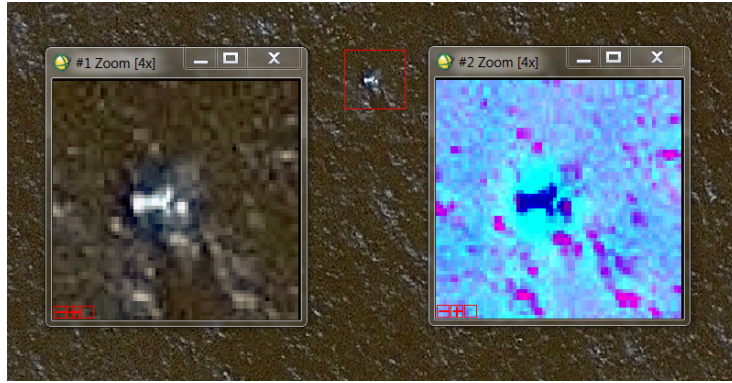


Figure 89: PHR_4 Image object 31 (Source: French Military Intelligence Service © CNES)



Figure 90: PHR_4 Image object 32 (Source: French Military Intelligence Service © CNES)

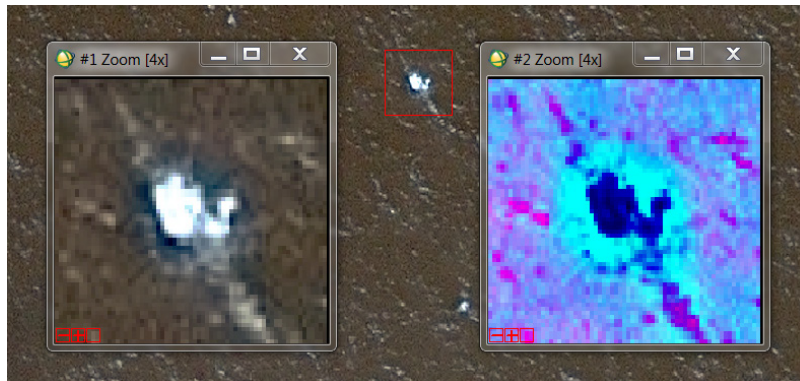


Figure 91: PHR_4 Image object 33 (Source: French Military Intelligence Service © CNES)

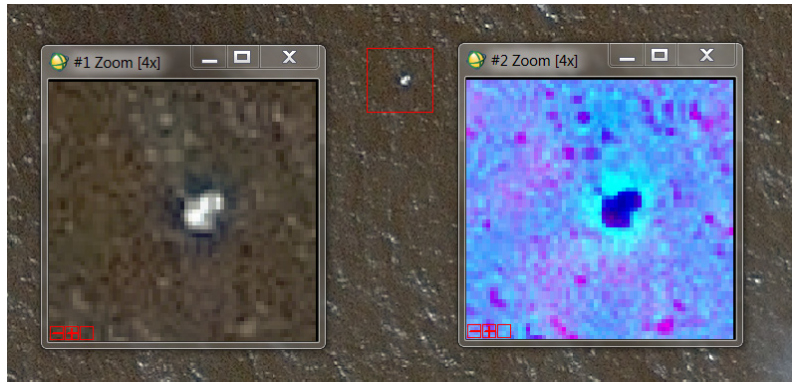


Figure 92: PHR_4 Image object 34 (Source: French Military Intelligence Service © CNES)



Figure 93: PHR_4 Image object 35 (Source: French Military Intelligence Service © CNES)

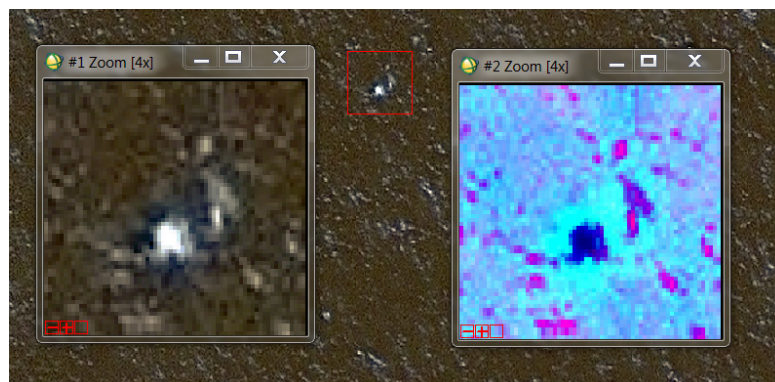


Figure 94: PHR_4 Image object 36 (Source: French Military Intelligence Service © CNES)