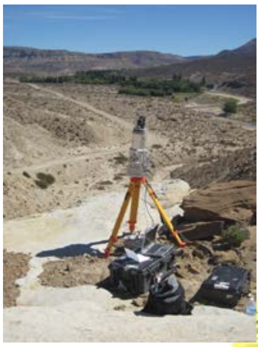
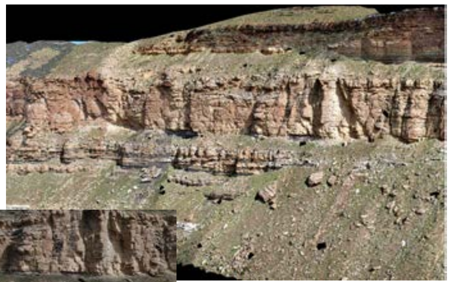
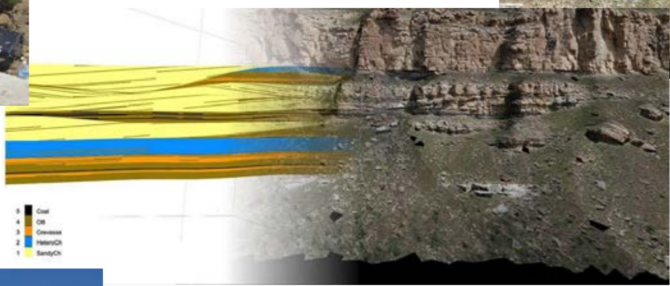
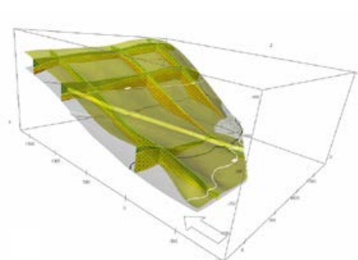
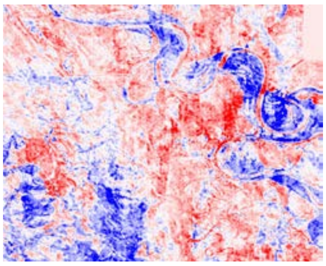
A Database of Geological Analogues for Exploration and Production











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NOTE: This proposal contains unpublished material and should be therefore handled confidentially and not shared with third parties.

Proposers

The VOG group was formed in 2004 at the University of Bergen's centre for excellence in Petroleum Research (CIPR). The group focuses on the study of geological outcrops to address reservoir related challenges. The group is world-leading in the use of digital spatial data collection techniques in geological field studies, and pioneered the application of ground based and oblique-helicopter-mounted laser scanning (lidar) and ground-based hyperspectral scanning for improved characterisation of geological outcrops. A key aspect of the data collection is the building of geocellular reservoir models from outcrops. The group's largest project is SAFARI (www.safaridb.com) which involves building a database of outcrop information for improved reservoir modelling.

In 2013, John Howell moved to the University of Aberdeen which has a long and established history in petroleum-related geological research. The group is now spilt between the two institutions, with the geomatics portion based in Uni CIPR in Bergen, and the geological part in Aberdeen. In addition to John Howell and Simon Buckley who run the group it includes 4 post docs, 12 Phd students, 5 masters students and two programmers/developers. The group has access to three terrestrial laser scanners (including a state of the art Reigl VZ2000), a hyperspectral scanner with core scanning facility, 6 unmanned aerial vehicles (UAV), including a thermal drone and various surveying equipment. The Group has also developed its own software (Lime) for visualisation of virtual outcrop data. See www.org.uib.no/cipr/Project/VOG/ for more information.

SAFARI is the Groups biggest project. It is supported by 14 Oil Companies, the Norwegian Research Council and the NPD. The project has been running for ten years and is currently midway through Phase 3.

Current SAFARI project sponsors and partners

What is SAFARI?

SAFARI is a database of analogue information designed to facilitate better reservoir modelling and de-risking of exploration prospects. It contains data from outcrops, modern systems, shallow seismic, process based models and producing fields, all underpinned by a common data standard and accessed through a simple, secure web-portal. A unique aspect of the project is a **library of 110 "Virtual Outcrops"** which are accessed through a purpose built web viewer. SAFARI is a Joint Industry/Academia researcher project carried out at the University of Aberdeen and UniCIPR in Bergen funded by the oil industry, the Norwegian Research Council and the NPD. The project has been running since 2007 and is currently in its third phase. The total budget to date has been £4.1 million.

The fundamental concept behind the project is the importance of **analogues** as a tool for better understanding subsurface prospects and assets where data coverage is sparse and expensive to acquire. The goal of the project is to facilitate access to analogue data for the Oil Industry, especially with respect to production (building better reservoir models) and exploration (de-risking prospects). These analogue data traditionally come from outcrops and modern systems. The database includes information on **170 outcrops** with **3500+** geometric measurements. Over a **110** of those outcrops have 3D photorealistic virtual outcrops which can be viewed online. There are also a series of GIS tools to locate suitable **modern analogues** and data are currently being added from **producing fields** and **shallow seismic data**. The data are all linked by a common data schema (or standard) and are accessed through a secure web portal (SafariDB.com).

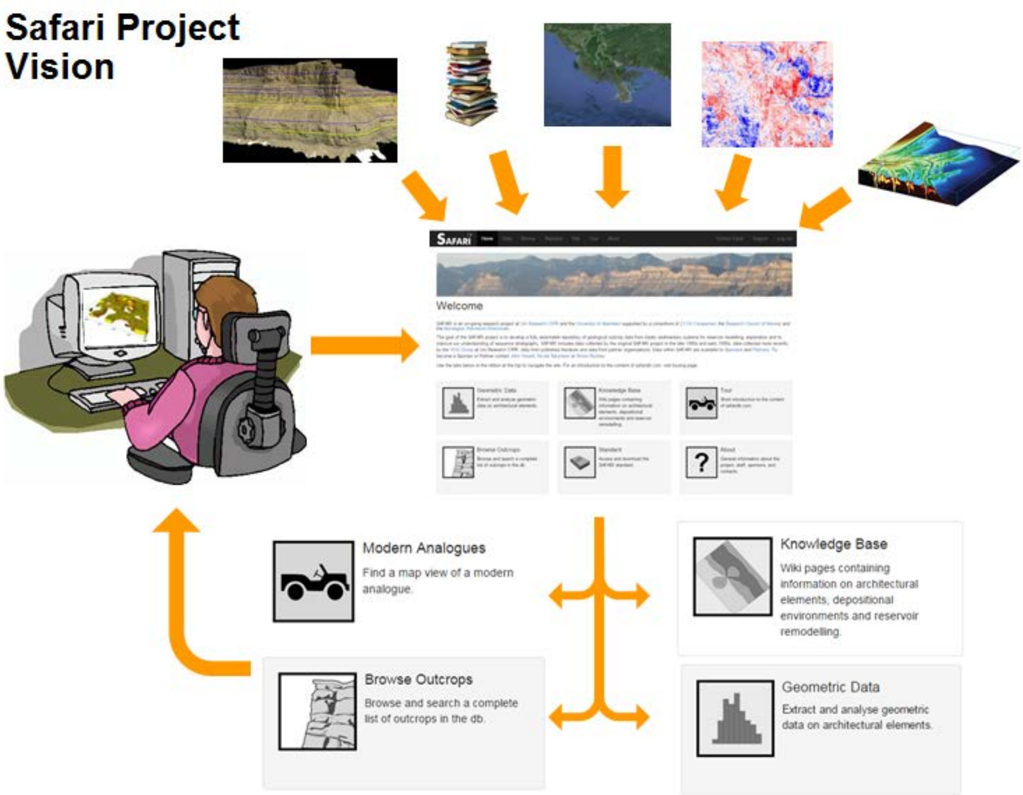

Figure 1 Project Vision. A web-based database for geoscientists that provides access to a host of analogue information for better population of geomodels, conceptual understanding and prospect de-risking

SafariDB – A quick overview

The SAFARI database is accessed via the web portal safaridb.com. It includes geometric data, a database of outcrops with Virtual Outcrops. There is also a tool for finding suitable modern analogues and a knowledge base that contains articles about all of the architectural elements, the stratigraphy of the North Sea and other relevant information.

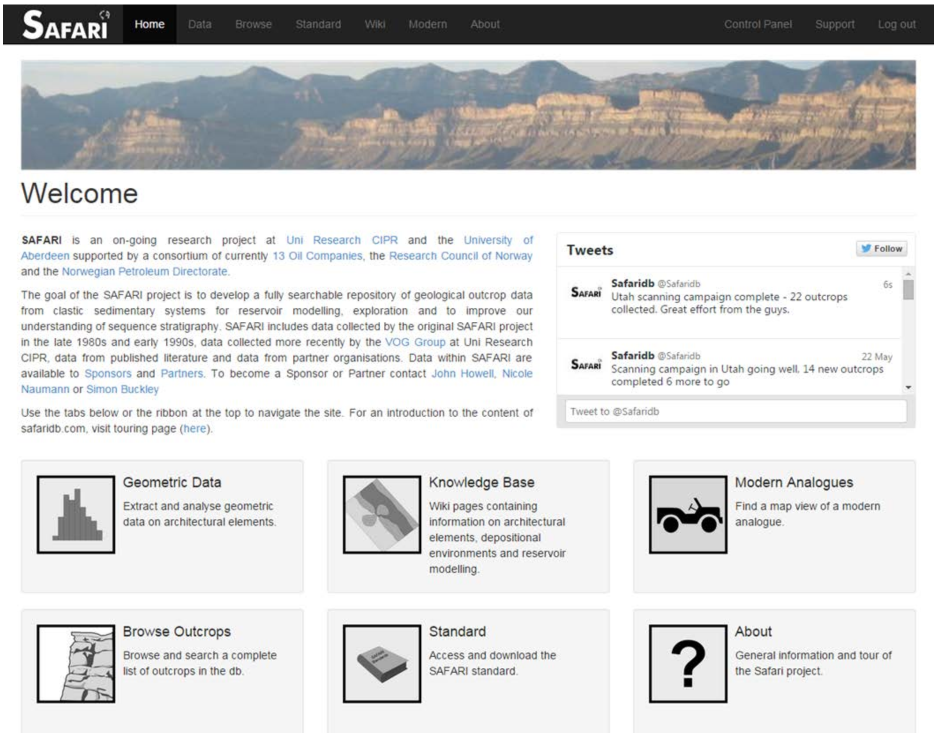

Fig 2. Front Page of safaridb.com. The grey boxes are links to the key components, the Geometric Data, the Modern Analogue Tool and the Browse Outcrop tools.

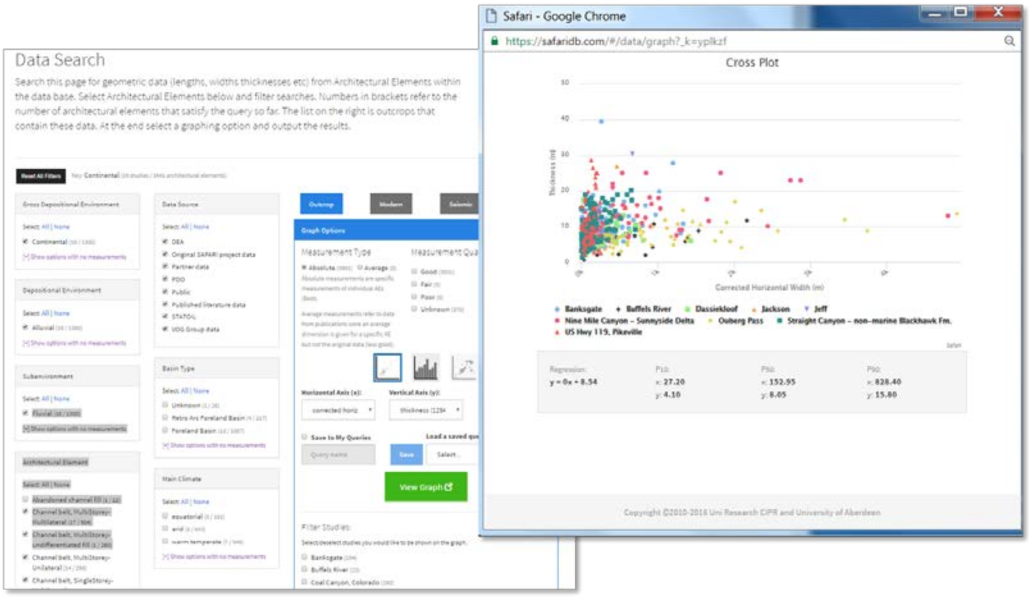

Fig 3. The Geometric Data search tool. Search for architectural elements by depositional environment. Filter by basin type, climate, data source etc. Display results as cross plots or histograms with statistics that can be used to populate reservoir models.

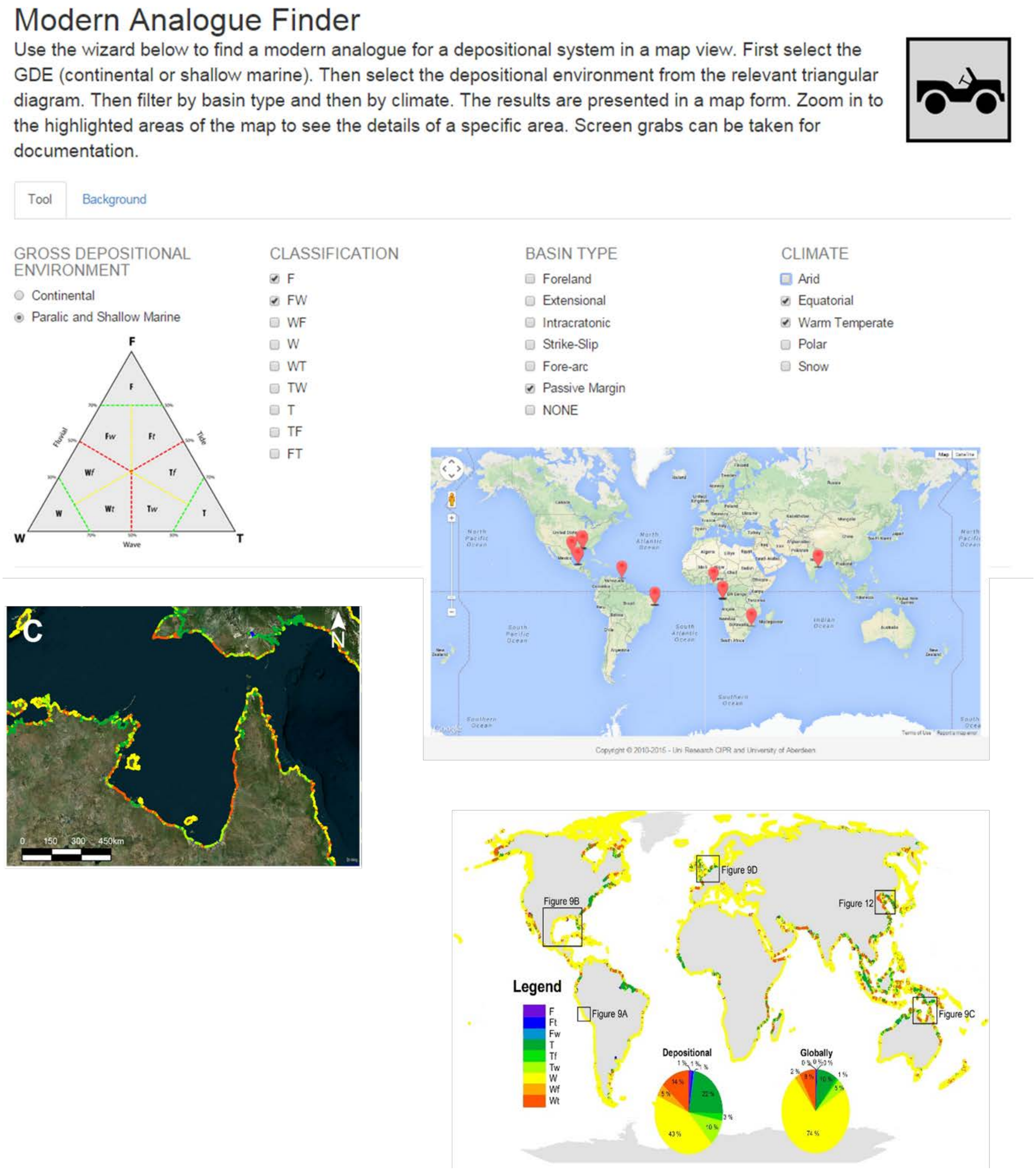

Figure 3. Modern Analogue Finder. Search in continental or shallow marine environments, then filter by basin type and climate. Results are presented in google maps as areas that satisfy the search criteria. Switch to satellite view to see the analogue. The system is fully auditable and repeatable. Based on the PhD work of Bjorn Nyberg

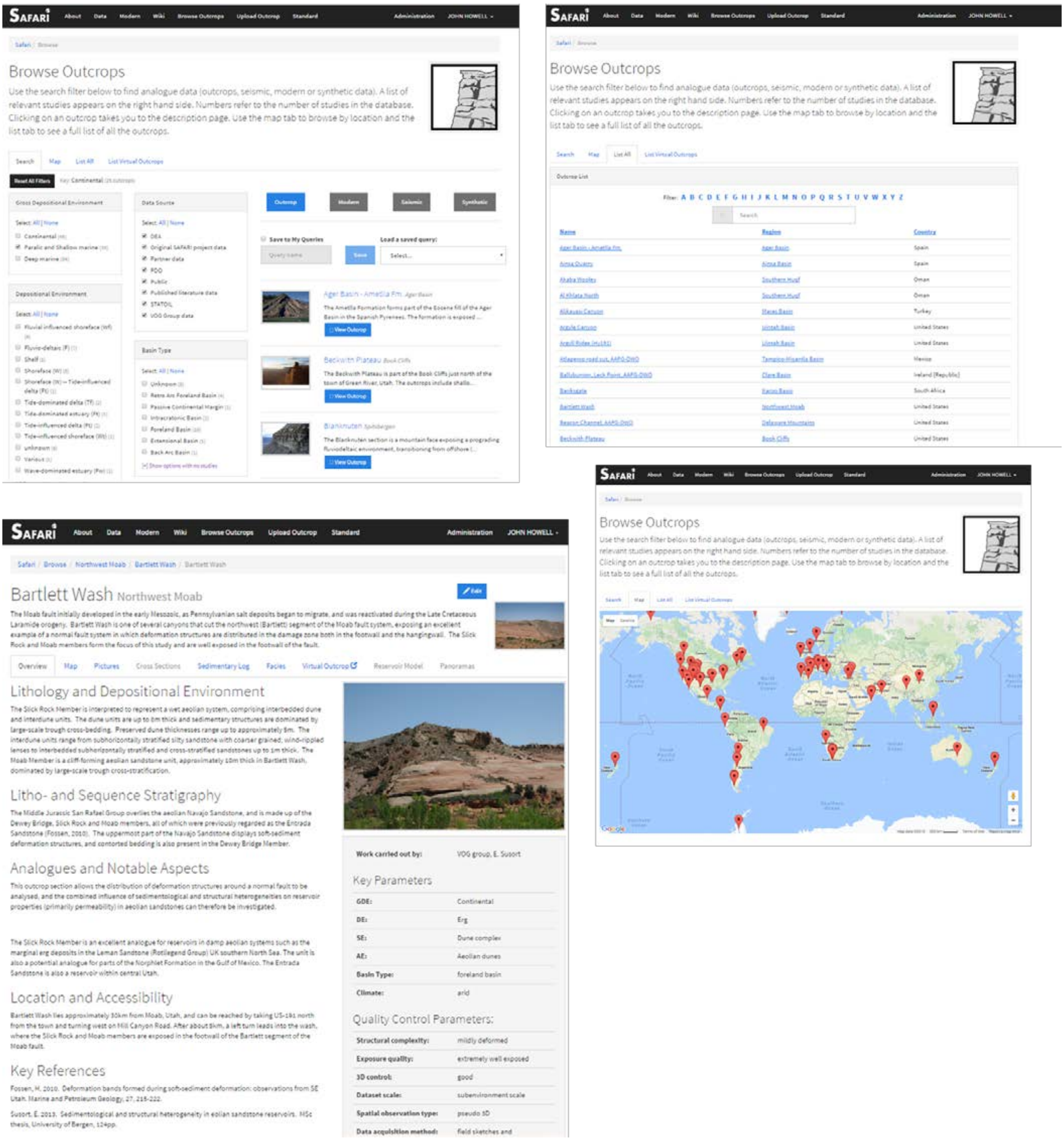

Figure 4. Find Outcrop tool. Find an outcrop by using a search tool, by browsing a list or on a map. Each outcrop has a standardised description page with additional tabs for logs, maps, photos and virtual outcrops. This part of the database contains 170 outcrops and is constantly growing.

History – Original Safari, Phase 1 and Phase 2

The original SAFARI project was undertaken between 1989 and 1994 by a consortium of Norwegian oil companies (Statoil, Norsk Hydro, Saga Petroleum) and the Norwegian Petroleum Directorate (NPD). This was one of the first projects to collect quantitative analogue data for reservoir modelling purposes, and resulted in a dataset of quantified heterogeneity data, as well as photos and text, from 13 different field analogues (outcrops) and 201 cross sections covering four depositional environments. However at that time, there was no proper database structure in which the data could be stored.

Around 2004 the SAFARI data were donated to the FORCE Sed/Strat group with the goal of building a digital database for outcrop data. The FORCE Sed/Strat group then took the initiative to enhance the database with new information collected using modern digital outcrop techniques. The Virtual Outcrop Group at Uni Research CIPR in Bergen took on the project in 2007. The Sed/Strat Group decided that this new project should be called SAFARI after the original pioneering work.

Since 2007 there have been three phases of the Project supported by 25 sponsors and the Norwegian Research Council. Phase 1 was focused on secure the old SAFARI data, building the data standard and developing new methods to collect “Virtual Outcrop” data including heli-lidar which allowed very large (10’s km) Virtual Outcrops to be acquired. Phase 1 included 1 Post Doc and 3 PhDs. Phase 2 focused on building the web accessible database (SafariDB.com) and studying modern systems. It included, one Post Doc, one Phd and a full time programmer. The key results of phase 1 and 2 can be summarised as:

- Developed a database standards for describing outcrop analogue data
- Built the database and web portal (SafariDB.com)
- Uploaded all of the original SAFARI data
- Developed new methods for collecting virtual outcrops with oblique helicopter mounted lidar and more recently drones
- Had 4 PhD and 25 masters students collecting, processing and interpreting data from across the World for the database
- Compiled geometrical data from published literature for fluvial, shallow marine and deep water systems
- Built web tools for online viewing of virtual outcrops
- Built an online tool for finding modern analogues based on depositional environment, basin type and climate.

More details on the earlier phases of the project, including a list of project deliverables, project sponsors and details of the personal involved can be found at the SafariDB website in the about section (https://safaridb.com/#/about?_k=444rpk)

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Phase 3 – Populating the database (2014 -)

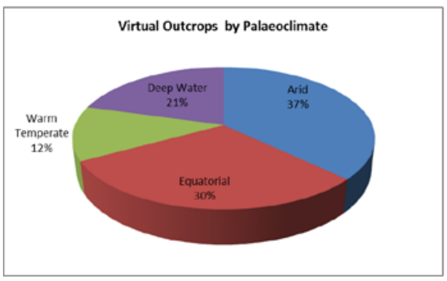
The theme for SAFARI 3 is populating the database which we built in phase 2, with large volumes of new data. These data come from a variety of sources including outcrops, seismic and production data, and are linked under the umbrella of the SAFARI schema. This standardised schema means that data from the different sources are comparable and searchable. The project deliverables include

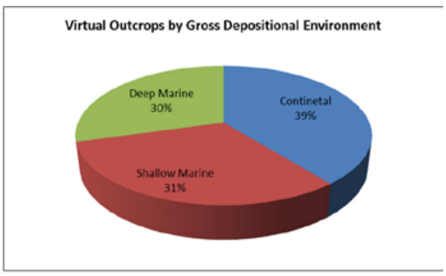
1. A comprehensive library of Virtual Outcrops (150+) which can be accessed by sponsors via the web portal or supplied for inhouse use by sponsoring companies
2. Geometric data from very shallow seismic (<0.5s) which provides high quality 3D information on body geometries
3. Oil field production data classified within the SAFARI standard which can be used to link depositional environment with a series of production measures (such as initial and maximum well rates, cumulative production, etc.)
4. New methods for utilising the virtual outcrops, especially through the development of workflows to generate MPS training images directly from the VO
5. Grow the database of outcrops and geometric data

The work is arranged into 5 work packages (WP) and is running over a 4 year period (note - sponsors only pay for 3 years):

WP 1 – Library of Virtual Outcrops – One hundred and fifty outcrops are being scanned using the group's terrestrial Lidar systems and recently developed UAV capability. Virtual outcrop models are being generated for all of these. A list of outcrops, decided upon by the steering committee, is included in Appendix A. New entrants are invited to suggest outcrops that are not already included which are of special interest to them. The goal is to cover of all the clastic depositional environments within the SAFARI Standard, from a wide range of localities and settings (Fig 5).

A key part of SAFARI 2 was building a web viewer that allows users to interact with 3D virtual outcrops over the web. This is a significant development because it removes the need for installing software locally. The database now allows users to search and find suitable outcrop analogues and then take "mini-fieldtrips" around the VO to view stratal architecture, facies relationships and measure dimensions from their desk. Thus improving the utilisation of outcrop data in the daily workflow. Data are analysed and interpreted by PhD and masters students both at UoA and partner institutes. Once completed the interpretations are incorporated into the database.





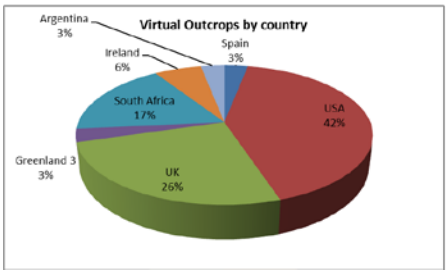


Fig 5. Virtual Outcrops by country, palaeoclimate and depositional environment

WP 2 – Architectural elements from 3D seismic data – These data provide the opportunity to quantify depositional systems and their component individual architectural elements in three dimensions over regional scales (many tens of kilometres), complementing outcrop studies within the SAFARI database. We have negotiated access to a series of regionally extensive 3D seismic volumes that cover a range of fluvial, shallow marine and deep marine gross depositional environments and allow quantification of planform, cross-sectional and neighbour relationship data for component architectural elements. All mapped architectural elements will be categorised within the standard SAFARI framework. This work is currently being undertaken by two PhD students who are focusing initially on the PGS Mega-Survey.

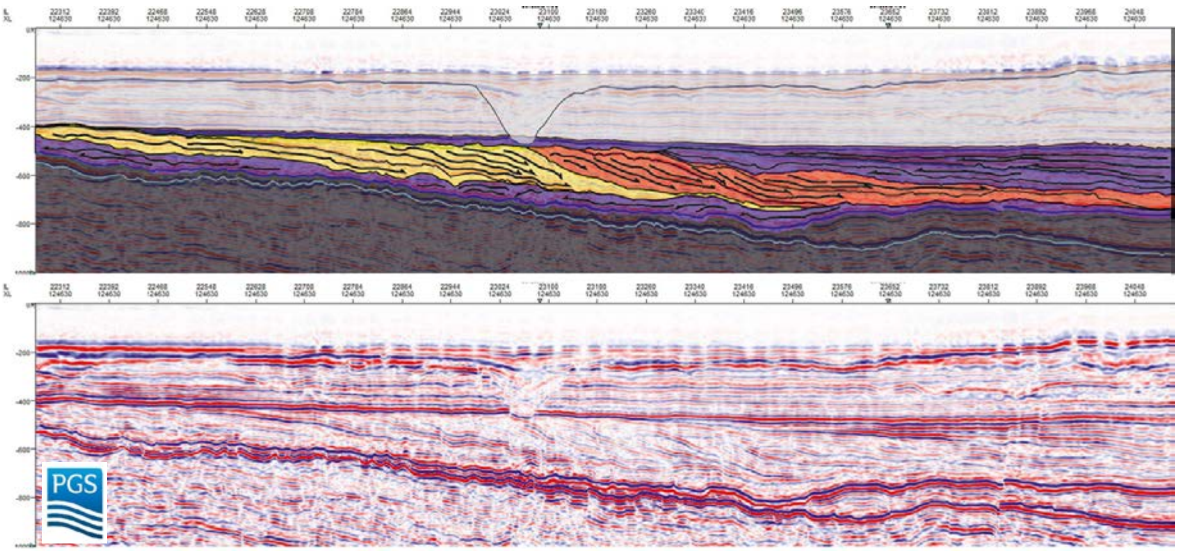


Fig 6. Example of shallow seismic data from the Dornoch Delta in the Moray Firth. Data courtesy of PGS, from the PhD of Eva Zimmer.

WP 3 – Production data – significant volumes of publically available production data exist for the Norwegian Continental Shelf. All of the existing fields on the NCS will be categorised within the SAFARI Standard including additional parameters to describe depth of burial, max depth of burial, phase, aquifer size etc. to investigate the facies control on production and to allow for the rapid access to suitable analogues for other subsurface fields. This work is currently being undertaken by a PhD student who has just started his studies.

WP 4 – Database development and management to include running the existing database, expansion to account for the new data types and uploading of further data from the literature. This work is undertaken by the project team in Bergen and Aberdeen, coordinated by Nicole Naumann. IT support and database hosting is provided by OMTT in Norway.

WP 5 – VOM to MPS This part of the project is funded by the Norwegian Research Council and is developing methodologies and workflows for extracting more geometric and numerical data from the virtual outcrop models (VOM). Special reference is based upon tools that will allow VOMs to be used as training images for multi-point statistics. This work includes two PhD students, one at Aberdeen and one in Bergen.

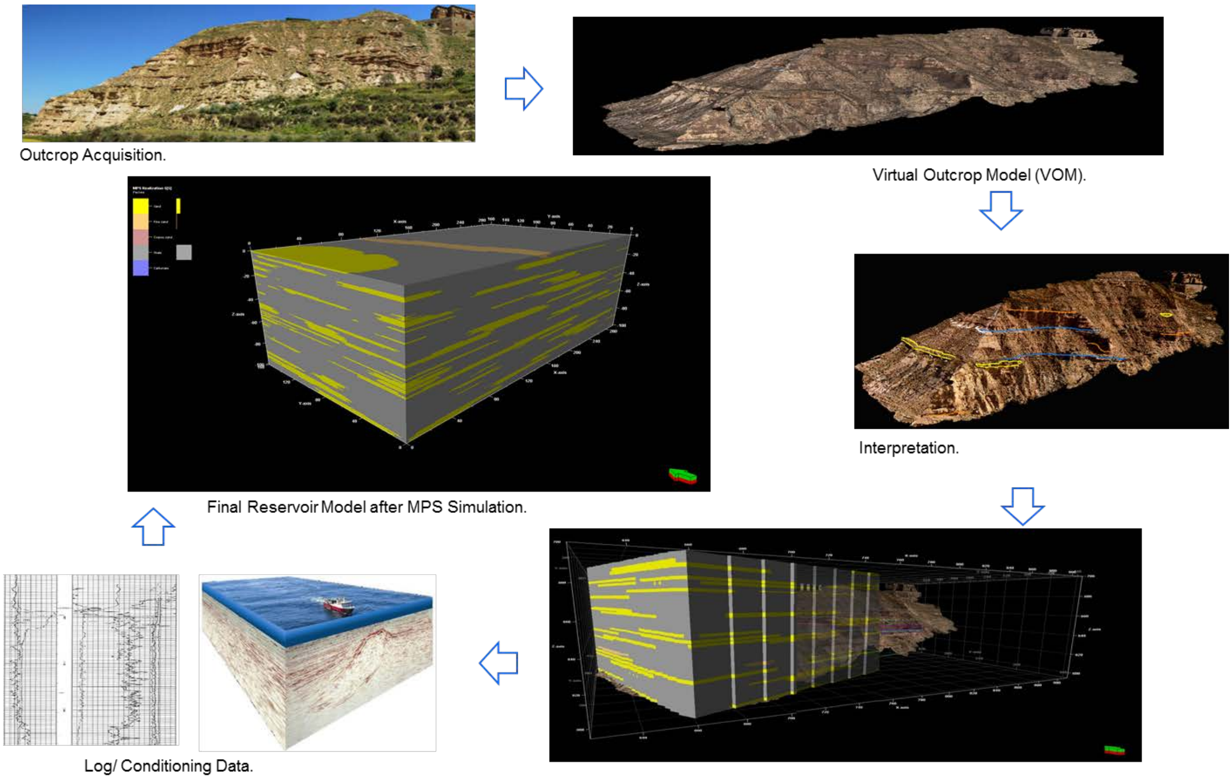


Fig 7. Workflow for VOM to MPS. From the PhD of James Mullins

Funding, timing and governance

The project is funded by a consortium of oil companies, the Norwegian Research Council and the NPD. The total project budget to date is 14.4 mnok. Details of the cost to join the project as a sponsor are available from John Howell or Nicole Naumann. Joining the project gives unlimited access across the Company.

The project started in 2014 as Phase 2 finished. The project will continue into 2018. The project is co-ordinated by Howell in Aberdeen and the Norwegian part by Naumann in Bergen. The Petromax part of the project (WP5) is co-ordinated by Simon Buckley at Uni CIPR in Bergen. **Project governance** is via **a bi-annual steering committee meeting** held in March and September at the NPD in Stavanger. The steering committee is chaired by Kevin Keogh from Statoil. At these meetings the project team report on progress and future direction is discussed and decided upon. Each sponsoring company has one seat at steering committee meeting.

Timescale

The project started in 2014 and will continue for 4 years until 2017. Funding is for three years calendar years.

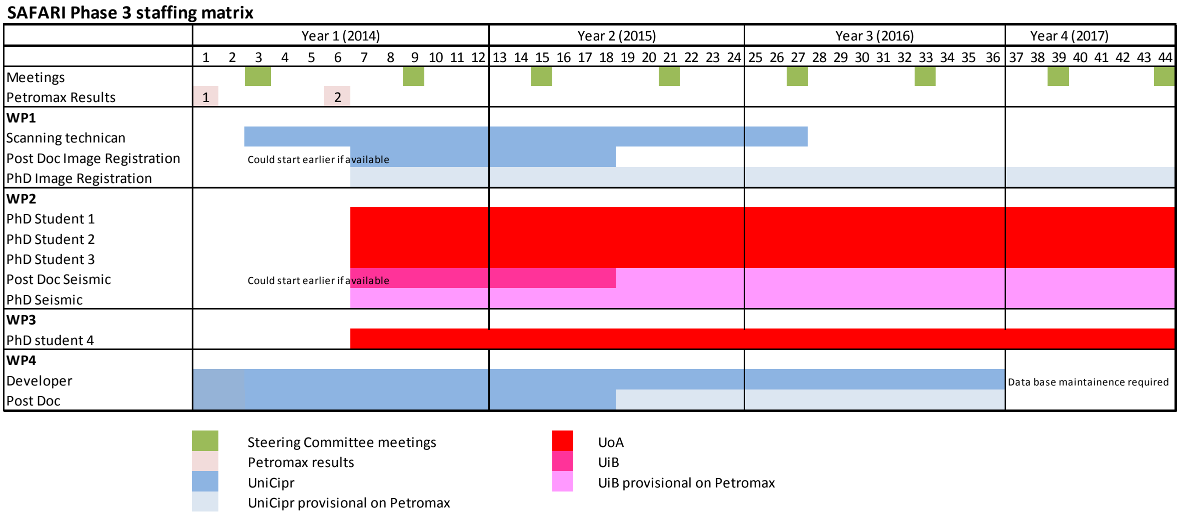


Fig 8. Project Timeline and Staffing

Appendix I List of current Virtual Outcrops in database

Outcrops scanned in Safari 3

	Phase	Name	Country	Age	GDE	Climate
1	3	Mam Tor (UK)	UK	Carb	Deep Water	NA
2	3	Brimham Rocks (UK)	UK	Carb	Continental	Equatorial
3	3	Alport Castle (UK)	UK	Carb	Deep Water	NA
4	3	Page Sandstone	USA	Jur	Continental	Arid
5	3	Shootaring	USA	Jur	Continental	Arid
6	3	Post	USA	Jur	Paralic/SM	Equatorial
7	3	Dominguez	USA	Jur	Continental	Arid
8	3	BlindTrailMesa	USA	Cret	Paralic/SM	Equatorial
9	3	Atkinson	USA	Jur	Continental	Arid
10	3	Little Park	USA	Jur	Continental	Arid
11	3	Labyrinth	USA	Cret	Paralic/SM	Equatorial
12	3	Ketobe Knob	USA	Jur	Continental	Arid
13	3	Canyonlands Kanyenta	USA	Jur	Continental	Arid
14	3	Woodside	USA	Cret	Paralic/SM	Equatorial
15	3	KaneCreek	USA	Triass	Continental	Arid
16	3	Hatch Mesa	USA	Cret	Paralic/SM	NA
17	3	CastleGateMine (roadcut)	USA	Cret	Continental	Equatorial
18	3	Woodside Channel	USA	Cret	Paralic/SM	Equatorial
19	3	Kayenta Colorado River Section1	USA	Jur	Continental	Arid
20	3	Takeout Beach	USA	Triass	Continental	Arid
21	3	Kayenta Roadcut	USA	Jur	Continental	Arid
22	3	Near Blaze	USA	Cret	Paralic/SM	Equatorial
23	3	Thompson	USA	Cret	Paralic/SM	Equatorial
24	3	Price Canyon	USA	Cret	Continental	Warm Temp
25	3	Bullfrog locality	USA	Jur	Continental	Arid
26	3	Panther Channel	USA	Cret	Paralic/SM	Equatorial
27	3	Kayenta Colorado River Section2	USA	Jur	Continental	Arid
28	3	Damaraland	Namibia	PreCam	Deep Water	NA
29	3	Etjo 1	Namibia	Jur	Continental	Arid
30	3	Etjo 2	Namibia	Jur	Continental	Arid
31	3	Rehy Hill	Ireland	Carb	Deep Water	NA
32	3	Kilclocher Cliffs	Ireland	Carb	Deep Water	NA
33	3	Kilredaun	Ireland	Carb	Deep Water	NA
34	3	Loop Head	Ireland	Carb	Deep Water	NA
35	3	Gull Island	Ireland	Carb	Deep Water	NA
36	3	Tullig point	Ireland	Carb	Paralic/SM	Equatorial
37	3	East Beach Whitby	UK	Jur	Paralic/SM	Equatorial
38	3	Cloughton Wyck	UK	Jur	Paralic/SM	Equatorial
39	3	Scalby Beach	UK	Jur	Continental	Equatorial
40	3	Burghead	UK	Triass	Continental	Arid
41	3	Clashac Quarry	UK	Perm	Continental	Arid
42	3	Ongeluks River	South Africa	Perm	Deep Water	NA
43	3	Klein riet Fontein	South Africa	Perm	Deep Water	NA
44	3	Katjiesberg	South Africa	Perm	Deep Water	NA
45	3	Klein Gemsbok	South Africa	Perm	Deep Water	NA
46	3	Hammerkranz	South Africa	Perm	Deep Water	NA
47	3	Lainsburg Dump	South Africa	Perm	Deep Water	NA
48	3	Skeiding	South Africa	Perm	Deep Water	NA
49	3	CD Ridge	South Africa	Perm	Deep Water	NA
50	3	Ouplaas	South Africa	Perm	Deep Water	NA
51	3	Buffles River	South Africa	Perm	Deep Water	NA
52	3	Zoutkloof	South Africa	Perm	Deep Water	NA
53	3	Simon's Town	South Africa	Ord	Paralic/SM	Arid
54	3	Chapmans Peak	South Africa	Ord	Paralic/SM	Arid
55	1	Banksgaten	South Africa	South Africa	Continental	Arid

56	1	Bartlett	Argentina	North America	Continental	Arid
57	1	Castlegate	USA	North America	Continental	Equatorial
58	1	Coal Canyon	USA	North America	Paralic/SM	Equatorial
59	1	Dassieskloof	South Africa	South Africa	Continental	Arid
60	1	Great Wall/Buffels River	South Africa	South Africa	Continental	Arid
61	2	La Bajada de los Molles (Lajas Fm.)	Argentina	South America	Paralic/SM	Equatorial
62	0	Nine Mile Canyon (CC)	USA	North America	Continental	Arid
63	1	Nine Mile Canyon	USA	North America	Continental	Arid
64	1	Ouberg	South Africa	South Africa	Continental	Arid
65	2	Pertusa	Spain	Spain	Continental	Arid
66	1	Tanqua Karoo	South Africa	South Africa	Deep Water	NA
67	1	Wasatch Plateau	USA	North America	Paralic/SM	Equatorial
68	1	Woodside (kenilworth)	USA	North America	Paralic/SM	Equatorial
69	0	Woodside (trail canyon)	USA	North America	Paralic/SM	Equatorial
70	1	Carlsberg Fjord	Greenland	E Greenland	Continental	Arid
71	1	Traill Ø	Greenland	E Greenland	All	Mixed
72	1	Hurry Inlet	Greenland	E Greenland	Paralic/SM	Warm Temp
73	1	Beckwith Plateau	USA	North America	Continental	Equatorial
74	2	Agrio	Argentina	South America	Paralic/SM	Equatorial
75	2	Ainsa (UAV)	Spain	Spain	Deep Water	NA
76	2	Bolea (UAV)	Spain	Spain	Continental	Arid
77	0	Garley canyon	USA	North America	Paralic/SM	Equatorial
78	0	Panther (Helper)	USA	North America	Paralic/SM	Equatorial
79	0	BullFrog1	USA	Jurassic	Fluvial	Arid
80	0	Bullfrog2	USA	Jurassic	Fluvial	Arid
81	0	Cainville	USA	Jurassic	Fluvial	Arid
82	0	ArgyllRidge	USA	Tertiary	Fluvial	Temp
83	0	HenryMountains	USA	Eocene	Igneous	Arid
84	0	Thompson	USA	Cretaceous	Paralic/SM	Equaotrial
85	3	La Jolla Beach	Mexico	Cretaceous	Paralic/SM	NA
86	3	Pinch Out Sst	Mexico	Cretaceous	Deep Water	NA
87	3	Skinny Channel Complex	Mexico	Cretaceous	Deep Water	NA
88	3	Camp Conglomerate	Mexico	Cretaceous	Deep Water	NA
89	3	Playa Escolete	Mexico	Cretaceous	Deep Water	NA
90	3	Collapsed external Levee	Mexico	Cretaceous	Deep Water	NA
91	3	San Carlos MTC	Mexico	Cretaceous	Deep Water	NA
92	3	Collapsed internal levee	Mexico	Cretaceous	Deep Water	NA
93	3	BFO Sand	Mexico	Cretaceous	Deep Water	NA
94	3	CCS5 Cliffs	Mexico	Cretaceous	Deep Water	NA
95	0	Brothers Point	UK	Jurassic/Palaeogene	Igneous	Temperate
96	0	Elgol Main	UK	Jurassic	Paralic/SM	Temperate
97	0	Elgol 2	UK	Jurassic	Paralic/SM	Temperate
98	0	Glasnakielle	UK	Jurassic/Palaeogene	Igneous	Temperate
99	0	Glasnakielle 2	UK	Jurassic/Palaeogene	Igneous	Temperate
100	0	Kilt Rock	UK	Jurassic/Palaeogene	Igneous	Temperate
101	0	Neist 1	UK	Jurassic/Palaeogene	Igneous	Temperate
102	0	Neist 2	UK	Jurassic/Palaeogene	Igneous	Temperate
103	0	Neist 3	UK	Jurassic/Palaeogene	Igneous	Temperate
104	0	Burnistone Bay	UK	Jurassic	Paralic/SM	Equaotrial
105	0	Whitby West Cliff	UK	Jurassic	Paralic/SM	Equaotrial
106	0	Cloughton Bay UAV	UK	Jurassic	Paralic/SM	Equaotrial
107	0	Cummingston	UK	Permian	Continental	Arid
108	0	Clashach Quarry	UK	Permian	Continental	Arid
109	0	Burghead	UK	Triassic	Continental	Arid
110		Crawton Bay	UK	Devonian	Continental	Arid

Appendix 2.1

Safari Schema for depositional environments, sub-environments and architectural elements for continental systems

Gross depositional environment	Climate filter	Depositional Environment	Subenvironment	Architectural element (deposits) (in alphabetic order)
Continental	equatorial	Lake	Lacustrine delta	119, 120
			Lacustrine non-deltaic shoreline	117, 122
			Lacustrine	114, 118, 121, 123
		Alluvial	Alluvial fan	101, 125, 133, 134, 135, 136, 137
			Alluvial plain	128, 129, 130, 131, 132
			Fluvial	101, 103, 104, 105, 106, 107, 116, 125, 127, 128, 133, 135
			Incised valley (bedrock)	101, 103, 104, 105, 106, 107, 108, 109, 116, 124, 125, 126, 127, 128, 129, 130, 131, 133
			Incised valley (alluvium)	101, 103, 104, 105, 106, 107, 108, 109, 116, 124, 125, 126, 127, 128, 129, 130, 131, 133
			Overbank	108, 109, 124, 128
	arid	Erg	Dune complex	102, 111, 112,
			Sandsheet	113
		Lake	Lacustrine delta	119, 120
			Lacustrine non-deltaic shoreline	117, 122
			Sabkha	111, 138
			Lacustrine	114, 118, 121, 123
		Alluvial	Alluvial fan	101, 125, 133, 134, 135, 136, 137
			Alluvial Plain	128, 129, 130, 131
			Fluvial	101, 103, 104, 105, 106, 107, 116, 125, 127, 128, 133, 135
			Incised valley (bedrock)	101, 103, 104, 105, 106, 107, 108, 109, 116, 124, 125, 126, 127, 128, 129, 130, 131, 133
			Incised valley (alluvium)	101, 103, 104, 105, 106, 107, 108, 109, 116, 124, 125, 126, 127, 128, 129, 130, 131, 133
			Overbank	108, 109, 124, 128
	warm temperate	Lake	Lacustrine delta	119, 120
			Lacustrine non-deltaic shoreline	117, 122
			Lacustrine	114, 118, 121, 123
		Alluvial	Alluvial fan	101, 125, 133, 134, 135, 136, 137
			Alluvial plain	128, 129, 130, 131, 132
			Fluvial	101, 103, 104, 105, 106, 107, 116, 125, 127, 128, 133, 135
			Incised valley (bedrock)	101, 103, 104, 105, 106, 107, 108, 109, 116, 124, 125, 126, 127, 128, 129, 130, 131, 133
			Incised valley (alluvium)	101, 103, 104, 105, 106, 107, 108, 109, 116, 124, 125, 126, 127, 128, 129, 130, 131, 133
			Overbank	108, 109, 124, 128
	snow/polar	Erg	Dune complex	102, 111, 112,
			Sandsheet	113
		Lake	Lacustrine delta	119, 120
			Lacustrine non-deltaic shoreline	117, 122
			Lacustrine	121, 123
		Alluvial	Alluvial fan	101, 125, 133, 134, 135, 136, 137
			Alluvial plain	128, 129, 130, 131, 132
			Fluvial	101, 103, 104, 105, 106, 107, 116, 125, 127, 128, 133, 135
			Incised valley (bedrock)	101, 103, 104, 105, 106, 107, 108, 109, 116, 124, 125, 126, 127, 128, 129, 130, 131, 133
			Incised valley (alluvium)	101, 103, 104, 105, 106, 107, 108, 109, 116, 124, 125, 126, 127, 128, 129, 130, 131, 133
			Sub-glacial	not yet defined
			Peri-glacial	not yet defined

Architectural Elements Key

Abandoned channel fill	101	Lacustrine distributary channel	120
Aeolian dunes	102	Lacustrine mudstone	121
Channel belt, MultiStorey-Multilateral	103	Lacustrine shoreface deposit	122
Channel belt, MultiStorey-Unilateral	104	Lacustrine turbidite	123
Channel belt, SingleStorey-Multilatera	105	Levee complex	124
Channel belt, SingleStorey-Unilateral	106	Mid-channel bar	125
Channel belt, undifferentiated fill	107	Modern channel	126
Crevasse channel	108	Modern channel belt	127
Crevasse splay sheet	109	Overbank mudstone	128
Damp interdune	110	Paleosol, immature	129
Damp sabkha	111	Paleosol, mature	130
Dry interdune	112	Paleosol, undifferentiated	131
Dry sandsheet	113	Peat/coal deposit	132
Evaporite	114	Point bar	133
Fluvial sheetflood	116	Sheetflood deposit	134
Lacustrine beach deposit	117	Side-attached bar	135
Lacustrine carbonate	118	Sub-aerial debris flow deposit	136
Lacustrine delta mouth bar	119	Undifferentiated sheet	137
		Wet sabkha	138

Appendix 2.2

Safari Schema for depositional environments, sub-environments and architectural elements for paralic and shallow marine systems

Gross depositional environment	Depositional Environment (Element Complex)	Subenvironment	Architectural element (deposits) (in alphabetic order)
Paralic and Shallow marine	F: Fluvio-deltaic	Delta top	132, 207, 209,
		Delta front	208, 217, 242
		Prodelta	221
	Ft: Tide-influenced delta	Delta top	207, 209, 132, 233, 25, 234, 236,237 , 238 239, 240
		Delta front	208, 217, 242
		Prodelta	221, 223
	Fw: Wave-influenced delta	Delta top	132, 207, 209,
		Delta front	208, 217, 242
		Prodelta	221, 223
	W: Shoreface	Backshore	207, 132, 229
		Foreshore	203, 204, 205, 206
		Shoreface	218, 222, 220
		Offshore transition zone	219, 223
	Wt: Tide-influenced shoreface	Backshore	207, 132, 22, 229, 231, 233
		Foreshore	204, 205, 212, 213, 214
		Shoreface	218, 222, 220
		Offshore transition zone	219, 223
	Wf: Wave-dominated delta	Delta top	207, 209, 132
		Foreshore	203, 204, 205, 206
		Shoreface	218, 222, 220
		Offshore transition zone	219, 223
	T: Tidal shoreline - non-deltaic	Supra-tidal flat	132, 228, 229, 231, 233
		Inter-tidal flat	212, 213, 231, 214,
		Sub-tidal	226, 227, 231
		Offshore transition zone	219, 223
	Tw: Wave-influenced tidal shoreline	Supra-tidal flat	132, 228, 229, 231, 233
		Inter-tidal flat	203, 204, 205, 212, 213, 214, 231
		Sub-tidal	226, 227, 231
		Shoreface	218, 222, 220
		Offshore transition zone	219, 223
	Tf: Tide-dominated delta	Delta top	207, 209, 132, 233, 235, 236, 237
		Delta front	208, 217, 242
		Prodelta	219, 223
	W: Barrier island	Lagoon	215, 216
		Barrier	207, 210, 211, 132, 232, 241, 243
		Foreshore	203, 204, 205
		Shoreface	218, 220, 222
		Offshore transition zone	219, 223
	Wf: Wave-dominated estuary	Bay head	202, 209, 132
		Central basin	201, 215, 216
		Barrier inlet	207, 210, 211, 132, 232, 251, 243
		Foreshore	203, 204, 205, 206,
		Shoreface	218, 222, 220
		Offshore transition zone	219, 223
	Wt: Tide-influenced barrier island	Lagoon	215, 216
		Barrier	207, 210, 211, 132, 231, 232, 251, 243
		Inlet	232
		Foreshore	203, 204, 205, 206,
		Shoreface	218, 222, 220
		Offshore transition zone	219, 223
	Tf: Tide-dominated estuary	Supra-tidal flat	132, 228, 229, 231, 233
		Inter-tidal flat	203, 204, 205, 212, 213, 214, 231
		Sub-tidal	226, 227, 231
	Shelf	Epicontinental shelf	223, 224, 225, 234
		Pericontinental shelf	223, 224, 225, 230, 234

Architectural Elements Key

Bay fill deposit	201	Sub-tidal bar	226
Bay head delta	202	Sub-tidal channel	227
Beach bar	203	Supra-tidal flat deposit	228
Beach deposit	204	Supra-tidal sabkha dep	229
Beach ridge/chenier	205	Tempestite	230
Berm	206	Tidal channel	231
Coastal dune	207	Tidal inlet channel	232
Delta mouth bar	208	Tidal point bar	233
Distributary channel	209	Tidal sandwave	234
Ebb-tidal delta	210	Tidally influenced fluvi	235
Flood-tidal delta	211	Tidally influenced fluvi	236
Inter-tidal bar	212	Tidally influenced fluvi	238
Inter-tidal flat deposit	213	Tidally influenced fluvi	239
Inter-tidal sabkha depos	214	Upper delta front depo	242
Lagoonal mudstone	215	Washover fan	243
Lagoonal sandstone	216	Mouth bar complex	244
Lower delta front depos	217	Trunk Channel	245
Lower shoreface deposi	218	Bay Fill Mudstone	246
Offshore transition zone	219	Middle Shoreface	247
Upper Shoreface	220	Sub-tidal flat	249
Prodelta deposit	221	Backshore	250
Rip channel	222	Barrier Island (undiff)	251
Shelf channel	223	Shoreface Shale	252
Shelf mudstone	224	Delta Lobe	253
Shelf turbidite	225	Lobe set	254

Appendix 2.3

Safari Schema for depositional environments, sub-environments and architectural elements for deep marine systems

Gross depositional environment	**Depositional Environment**	**Subenvironment**	**Architectural element** (deposits) (in alphabetic order)
Deep marine	Slope	Erosional confined channel belt complex	301, 304, 307, 309, 312, 313, 314, 315
		Erosional to levee confined channel belt complex	301, 304, 305, 307, 309, 312, 313, 314, 315, 316
		Slope - non turbidite	302, 306, 308
	Basin Floor	Unconfined levee channel belt complex	301, 312, 313, 314, 315, 316
		Lobe	311, 303
		Basin Floor - non turbidite	302, 306, 308, 310

Aggradational submarine channel belt	301
Contourite	302
Distal turbidite sheet	303
Erosional submarine channel belt	304
External submarine levee	305
Hemipelagic mudstone	306
Internal submarine levee	307
Mass transport complex	308
Passive submarine channel fill	309
Pelagic mudstone	310
Proximal turbidite sheet	311
Submarine debris flow deposit	312
Submarine meandering channel belt	313
Submarine outerbank bar	314
Submarine point bar	315
Undifferentiated submarine levee	316
Hybrid Beds	317
Slurry flow deposits	318