10.1071/PVv2010n148p35

Geotechnical hazards and seafloor stability of the northwest shelf

David White

James Hengesh

David White[1,2] and James Hengesh[1]

[1]*Centre for Offshore Foundation Systems, University of Western Australia.*
[2]*Email: white@civil.uwa.edu.au*

Introduction

Australia's vast undeveloped hydrocarbon reserves are located along remote parts of the coast, in water depths approaching 1500 metres, and at distances up to 1000 km from land. The safe, economical and reliable development of these reserves demands research into seabed characteristics, as well as new engineering techniques and technologies. This research is needed to assure that the offshore structures and pipelines necessary to enable production of these resources are engineered, designed, and constructed to perform adequately in these difficult environments.

Challenges

Two principal challenges related to exploitation of Australia's deep water oil and gas reserves are:

(i) to establish geohazard knowledge and engineering practices for this frontier region; and,
(ii) to create robust models for the near-seabed behaviour, where the infrastructure – pipelines or foundations – interacts with the ocean and weak seabed sediments.

Figure 1 illustrates the changing infrastructure requirements as hydrocarbon field development moves from shallow to deep water. In shallow water, production facilities are often located on fixed leg platforms and seabed sediments are commonly composed of sandy or cemented materials with favourable engineering properties. However, in deep water environments, production facilities are located on floating platforms that are anchored in place, pipelines and risers encounter very weak sediments and are susceptible to deep burial, and export lines must cross the continental shelf, where slope stability issues are common.

The engineering requirements for deep water developments shown on Figure 1 are representative of current trends off the coast of Australia and in most other major petroleum-producing regions. New projects off the Northwest Shelf are facing challenges associated with: (a) characterisation of the soft deep water carbonate sediments (presenting particular challenges); (b) characterisation of unstable zones of seafloor, including active faulting, landsliding and other geohazards; and (c), designing pipelines to cross steep, rugged and potentially unstable slopes, whilst accommodating thermal and pressure-induced expansions. At the ASEG Geophysics and Geohazards seminar in Perth, held in April 2010, we presented two key areas of research underway at COFS, which are addressing seabed pipeline design and seafloor stability.

Key research areas

The design methodologies to tackle each of these challenges are in their infancy, and beyond the regime of conventional engineering analysis. For example, an emerging technique to accommodate the in-service expansion and contraction of pipelines is controlled lateral buckling. In this design solution the pipeline is permitted to sweep back and forth across the seabed at engineered buckle locations, relieving the changes in length that occur during startup and shutdown. Industry guidelines are under development, through the SAFEBUCK Joint Industry Project (www.safebuck.com). COFS has contributed to the development of this guideline, through numerical and physical modelling of the interaction between pipelines and the seabed. Unlike conventional pipelines, which are designed to remain stationary once installed, seabed pipelines are required to move significant distances across the seabed, to safely alleviate stresses created during operation. We have developed new techniques for assessing the interaction forces when pipelines move across the seabed. These new techniques capture the changes in both seabed geometry and soil strength, which can fall and rise through episodes of remoulding and reconsolidation (Figure 2).

A second key research area within our group is the assessment of seafloor stability on the North West Shelf. In collaboration with the Western Australia Energy Research Alliance (WA: ERA), COFS is undertaking a multi-year project to improve our knowledge of geological hazard processes occurring along the

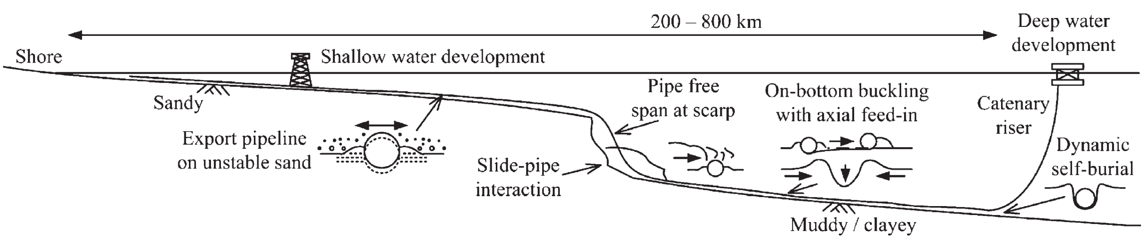

Fig. 1. *Changing infrastructure as hydrocarbon developments move into deeper water.*

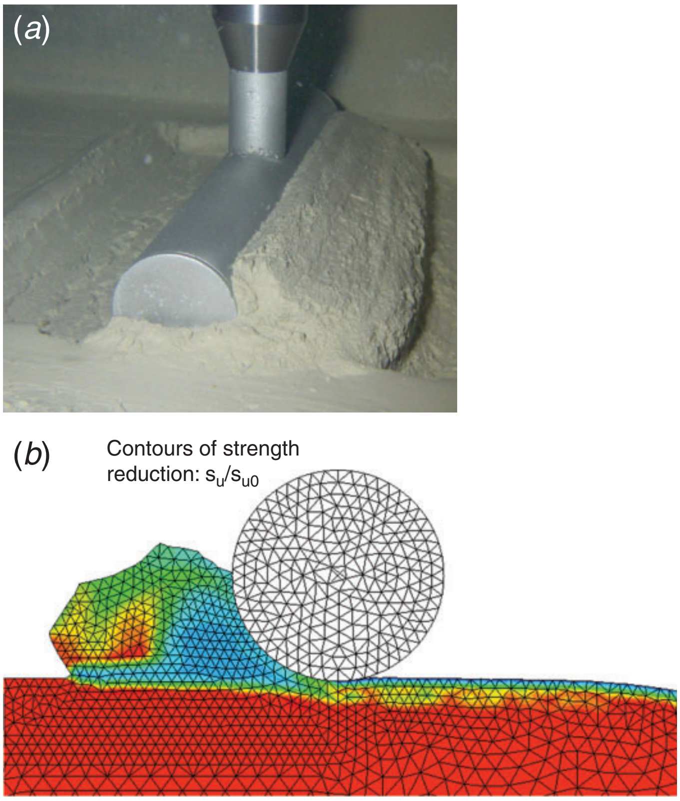

Fig. 2. *Physical and numerical modelling of pipeline-seabed interaction. (a) Geotechnical centrifuge modelling (Gaudin and White 2009). (b) Large deformation finite element analysis (Wang et al. 2010).*

Northwest Shelf. This is being achieved through the compilation and integration of both publically and privately held data related to seafloor morphology, geological structure and stratigraphic environments, geotechnical soil properties, and results from both laboratory and physical testing programmes. The results of the project will provide other researchers and industry with a comprehensive model of hazard processes along the Northwest Shelf.

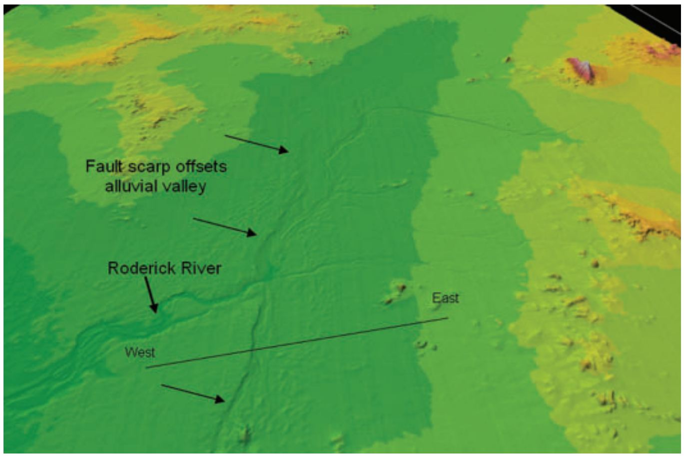

Fig. 3. *Digital elevation model showing recent fault scarps across Roderick River, Western Australia. Reproduced by permission of the Western Australian Land Information Authority (Landgate 2009).*

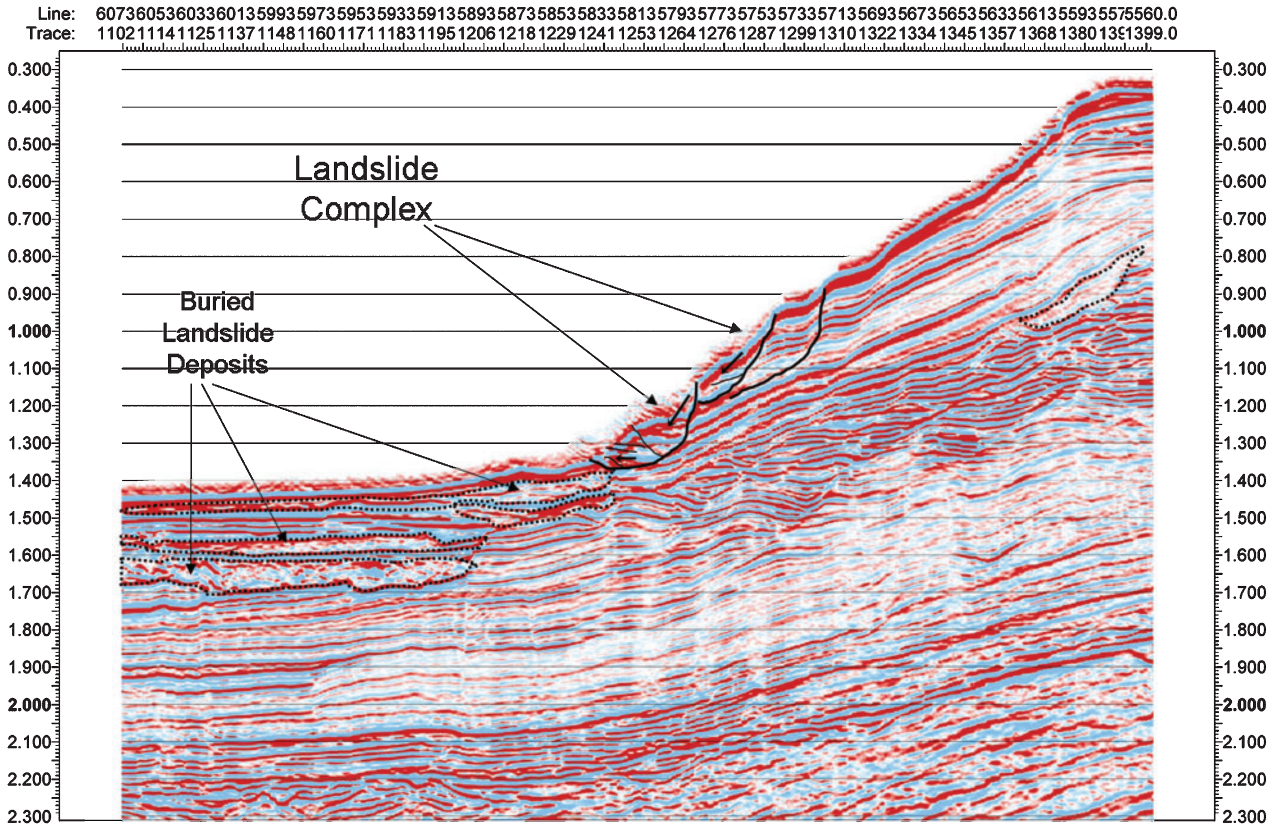

Fig. 4. *Landslide complex across the continental slope, Northwest Shelf, Australia.*

The Seafloor Stability Project involves three primary concentrations, including:

(1) ***Tectonic deformation and seismic hazards.*** Activities include: (i) documenting the location, style and rates of tectonic deformation (Figure 3); (ii) revising and updating the seismic source model for Australia's Northwest Shelf to improve inputs to ground motion assessments; and (iii) providing source parameters for assessment of site amplification, soil liquefaction and landslide triggering.
(2) ***Regional geomorphic analysis and landslide mapping.*** Activities include: (i) integrating seafloor data from multiple 3D seismic surveys to develop a composite high-resolution bathymetric map extending from the continental shelf across the continental slope to approximately 1500 m water depth; (ii) conducting detailed geological and geomorphological mapping to assess seabed processes, and locations and characteristics of marine geohazards (Figure 4); and (iii) developing a landslide inventory map and slope process model to assess slope process rates.
(3) ***Stability analysis and run-out modelling.*** Activities include: (i) documenting the length, width, height and thickness characteristics of submarine landslides; (ii) evaluating landslide triggering mechanisms; (iii) documenting slide run-out and flow pathways; and (iv) using field data to update and revise numerical models of landslide run-outs.

We anticipate that the integrated multidisciplinary approach to assessing conditions and processes in the deep marine environment off the Northwest Shelf will lead to significant developments in engineering that will improve the safety and reliability of oil and gas developments in these challenging environments.

References

Gaudin C., and White D. J., 2009, New centrifuge modelling techniques for investigating seabed pipeline behaviour. Proceedings of the XVIIth International Conference on Soil Mechanics & Geotechnical Engineering. Alexandria.
Landgate, 2009, 30 m digital elevation data, geospatial data CD-ROM; www.landgate.wa.gov.au
Wang, D., White, D. J., Randolph, M. F., 2010, Large deformation finite element analysis of pipe penetration and large-amplitude lateral displacement: *Canadian Geotechnical Journal* **47**, 842–856. doi:10.1139/T09-147