Projet ANR HYDRE

Anh Minh TANG
Ecole des Ponts ParisTech

Journée thématique SFT (22 janvier 2016)

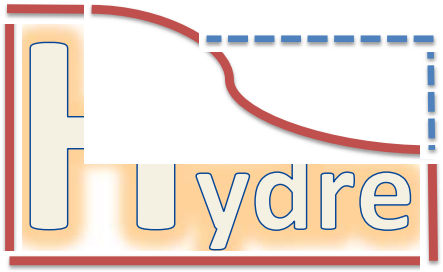
AGENCE NATIONALE DE LA RECHERCHE
ANR

Hydre

HYDRE

- Comportement mécanique des sédiments contenant des hydrates de gaz
- Partenaires:

- Début: 1er novembre 2015
- Durée : 42 mois
- Aide ANR: 800 k€
- Coût complet: 2 500 k€

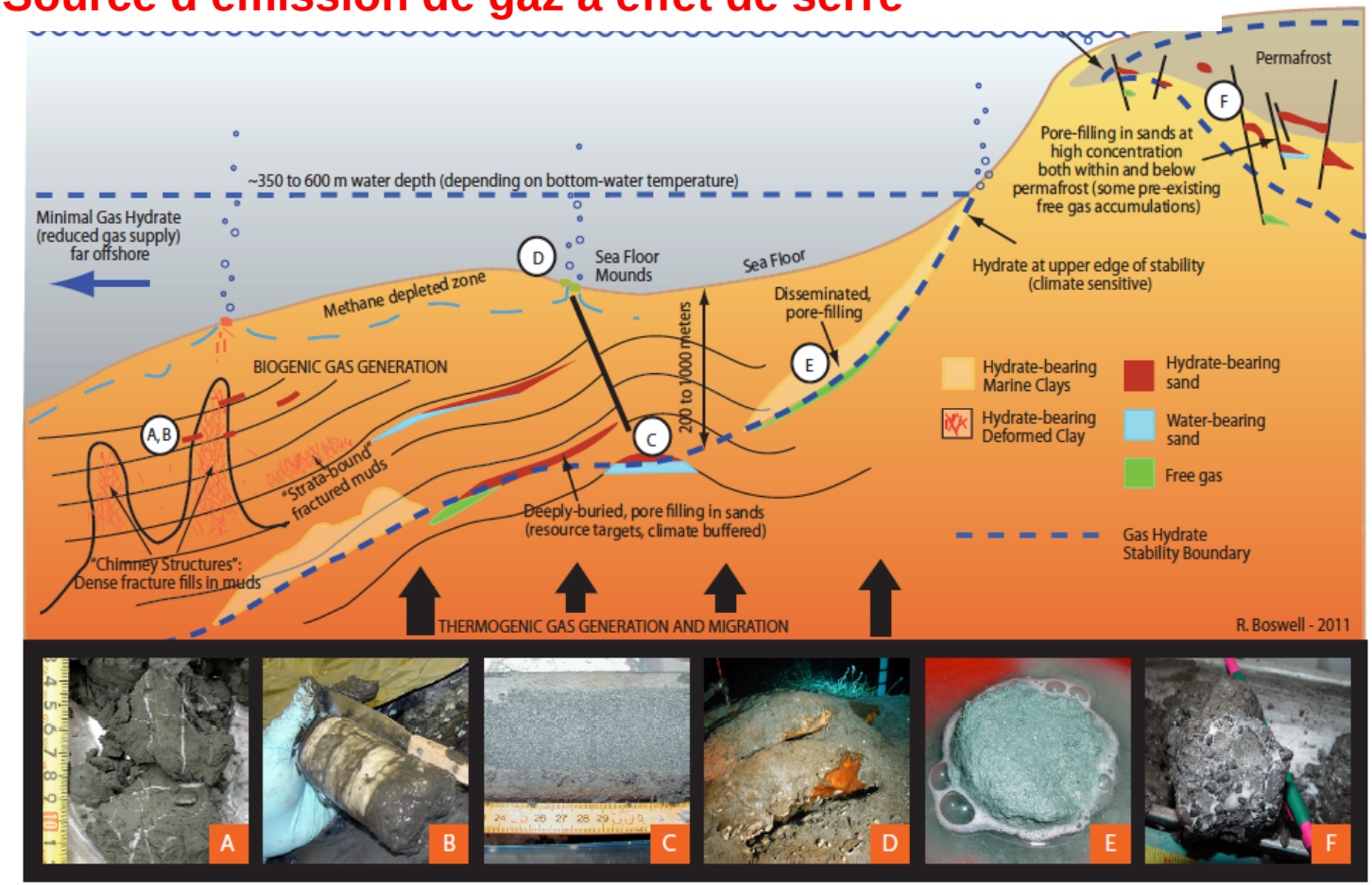


Contexte

Resource énergétique potentiellement importante

Source d'instabilité de talus continentaux

Source d'émission de gaz à effet de serre



http://www.methanegashydrates.org

Objectif

Etudier le comportement mécanique des sédiments contenant des hydrates de gaz afin de pouvoir réduire l'impact environnemental de leur potentielle exploitation future

Verrous

- Mécanismes de formation et de dissociation des hydrates dans les sédiments
- Influence de la présence des hydrates sur le comportement mécanique des sédiments
- Détection à partir des mesures in situ de la présence des hydrates
- Adaptation des dispositifs expérimentaux existants aux conditions de haute pression et basse température nécessaires à la formation des hydrates

Etat de l'Art

Documentaire Arte (2014): Méthane, rêve ou cauchemar

COST MIGRATE (1405): Marine gas hydrate - an indigenous resource of natural gas for Europe

Norway: http://www.cage.uit.no/

Germany: http://www.geomar.de/en/research/fb2/fb2-mg/projects/sugar-2-phase/

Japan: http://www.mh21japan.gr.jp/english/

USA: http://www.netl.doe.gov/research/oil-and-gas/methane-hydrates

New Zealand: http://www.gns.cri.nz/Home/Our-Science/Energy-Resources/Gas-Hydrates

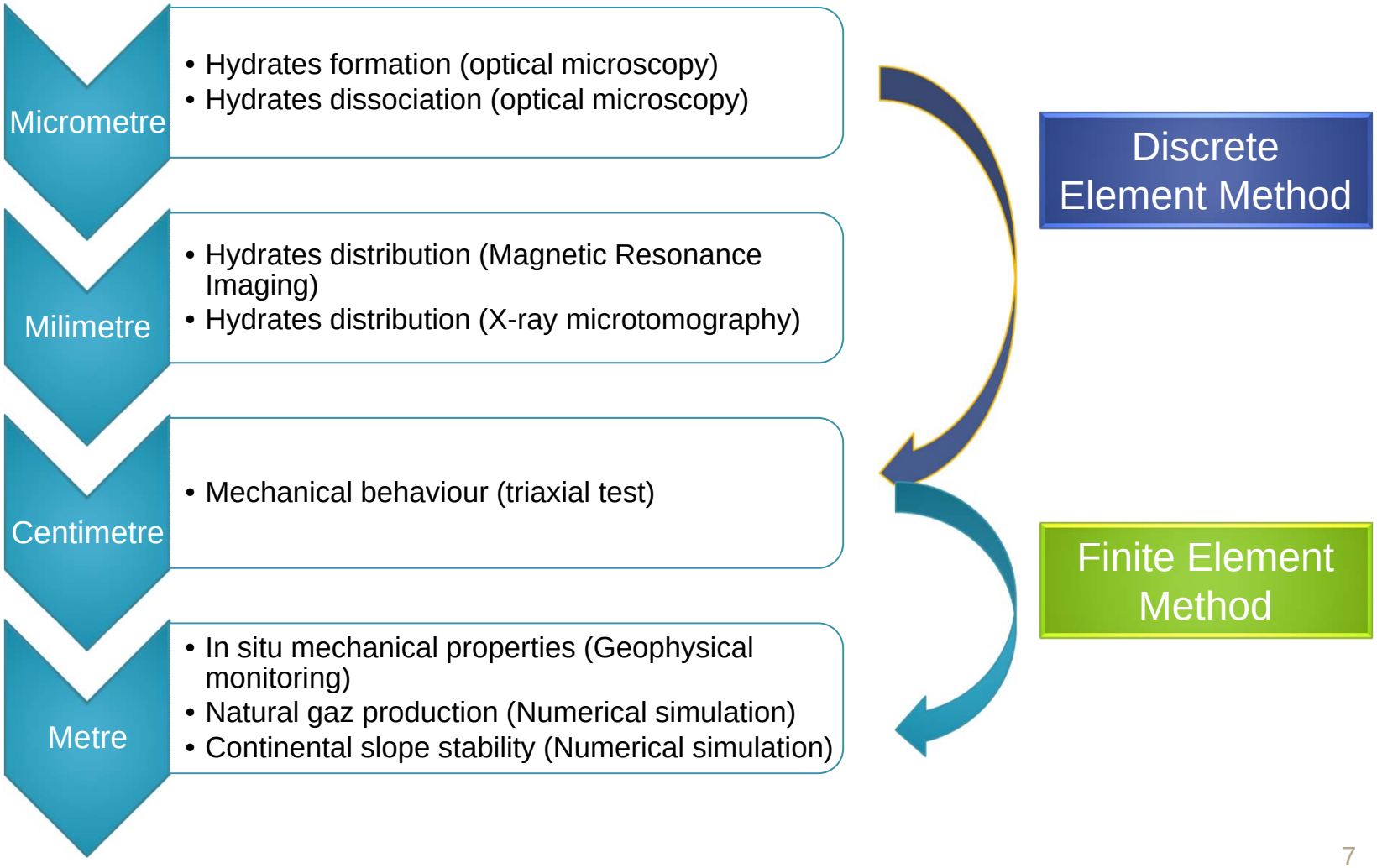
India: http://www.dghindia.org/NonConventionalEnergy.aspx

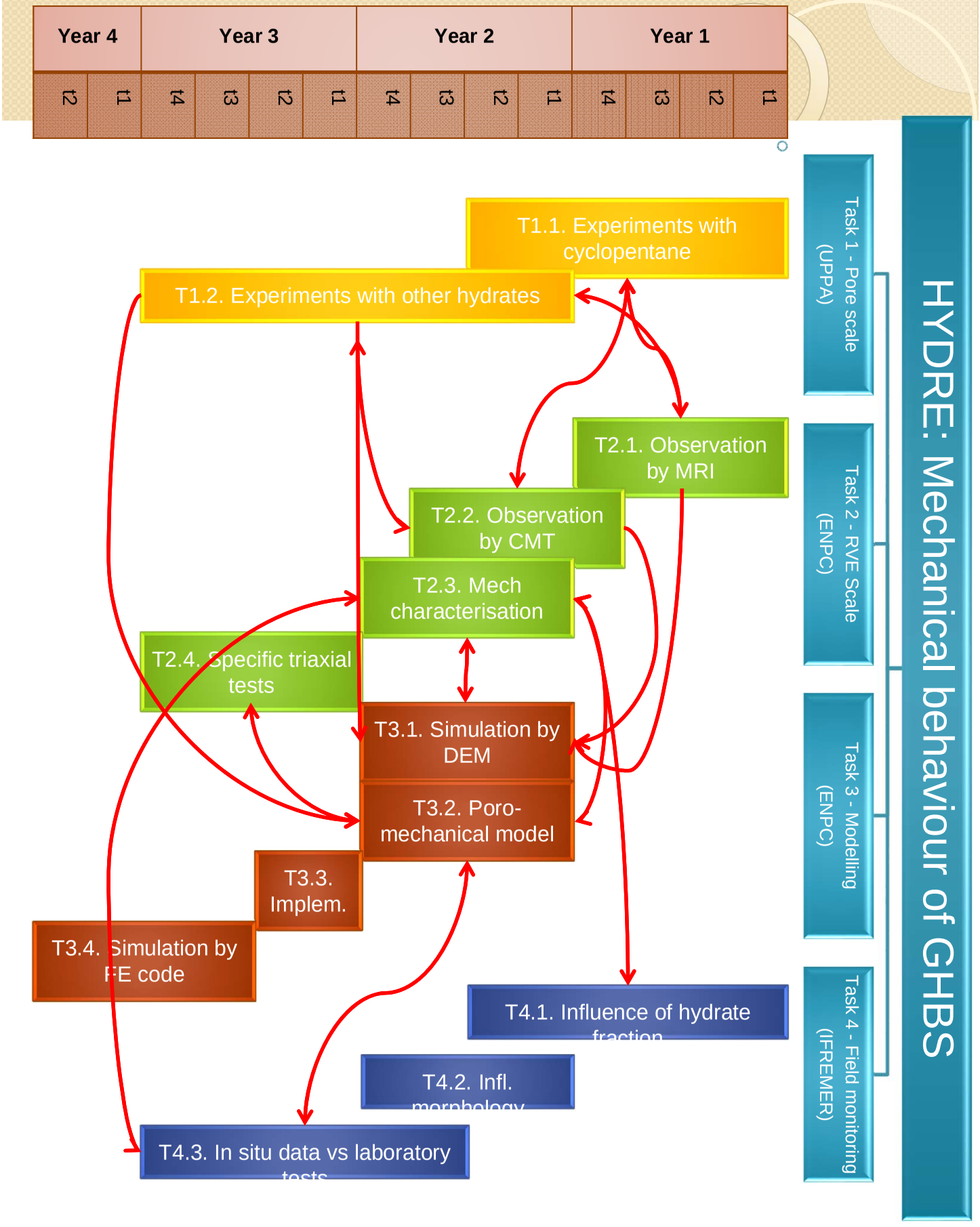
UNEP Report: http://www.methanegashydrates.org/

Journal "Fire in the Ice": http://www.netl.doe.gov/research/oil-and-gas/methane-hydrates/fire-in-the-ice

World Ocean Review: http://worldoceanreview.com/en/wor-3-overview/methane-

Programme scientifique



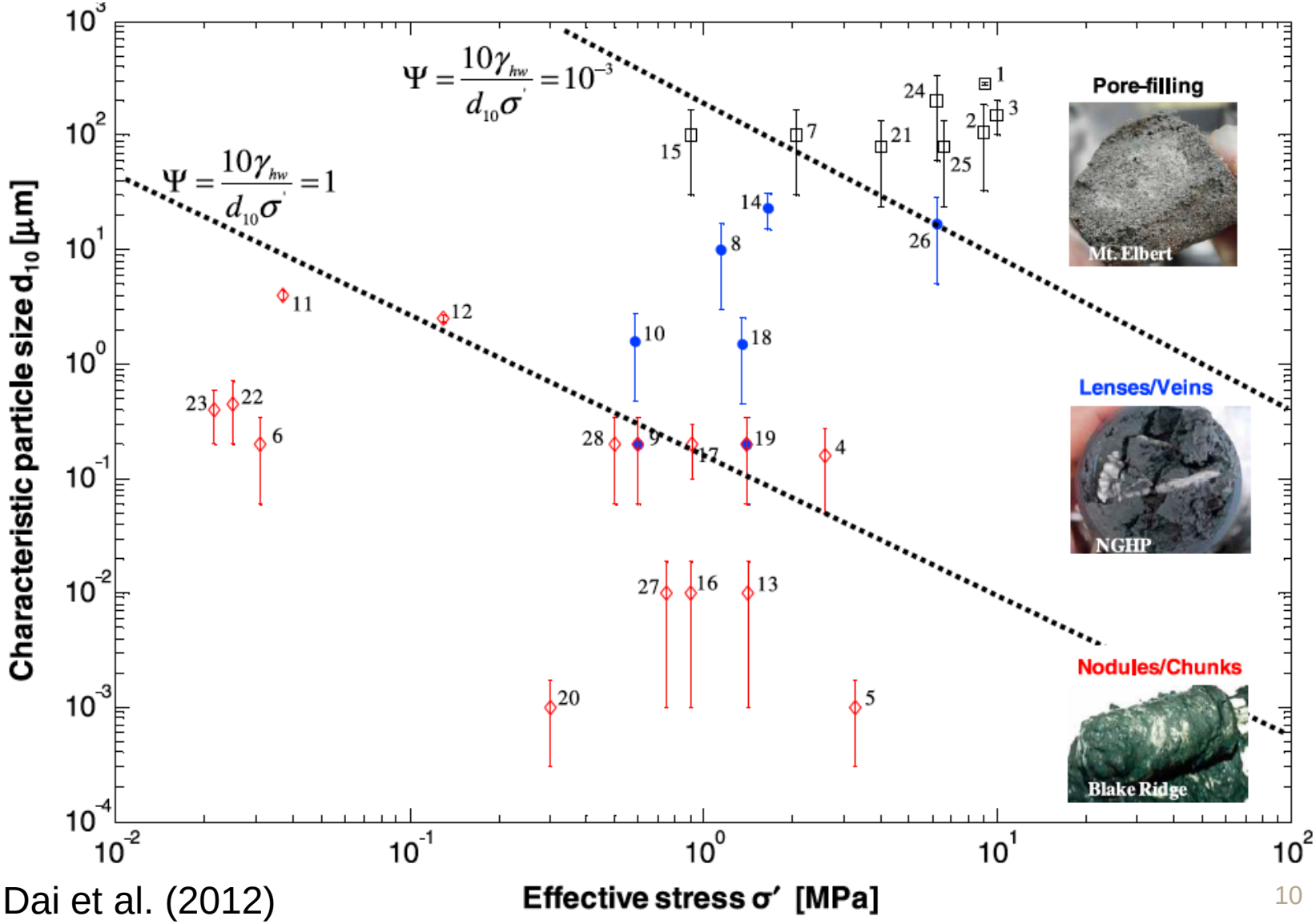

Year 4
Year 3
Year 2
Year 1
t2 t1 t4 t3 t2 t1 t4 t3 t2 t1 t4 t3 t2 t1
HYDRE: Mechanical behaviour of GHBS
Task 1 - Pore scale (UPPA)
Task 2 - RVE Scale (ENPC)
Task 3 - Modeling (ENPC)
Task 4 - Field monitoring (IFREMER)
T1.1. Experiments with cyclopentane
T1.2. Experiments with other hydrates
T2.1. Observation by MRI
T2.2. Observation by CMT
T2.3. Mech characterisation
T2.4. Specific triaxial tests
T3.1. Simulation by DEM
T3.2. Poro-mechanical model
T3.3. Implem.
T3.4. Simulation by FE code
T4.1. Influence of hydrate fraction
T4.2. Infl. morphology
T4.3. In situ data vs laboratory tests

Morphologie

Location	No.	Depth[b] (m)	Water Depth (m)	Hydrate Morphology	Sediment Description	Index Properties[c]	Mean	s.dev.	Typical Values
Mallik	1	913.7	913.7	pore filling	granular/pebbles (max 1 cm)	d_{10} = 275.9–292.9 μm (at 912.3 m)	285	8.5	
	2	903	903	pore filling	medium-grained sand	d_{10} = 108.4 μm (at 908.3 m)	108.4	76.02	
	3	892.8–1088.1	990.45	pore filling	medium/fine sands	d_{50} = 149.9–502.5 μm	150	50	fine/medium sands: 0.06–0.6 mm
Blake Ridge	4	259	3058.1	nodules	nanofossil-rich clay	d_{50} = 1.6 μm	0.16	0.11	
	5	330	3100.1	chunks	55%Illite + 45%Smectite		0.001	0.0007	Smectite: ~1 nm
	6	3.09	2781.59	nodules/chunks	soft clay (39.2% clay)	LL = 68; PL = 24	0.2	0.14	Kaolinite: ~0.1–1 μm
Nankai Trough	7	207.8–260	1178.9	pore filling	sandy sediments		100	70.13	fine/medium sands: 0.06–0.6 mm
	8	90–140	4799.3	veins	60% sand/granules + 40% silt		10	7.01	silt: 2–60 μm
NGHP	9	60	1300	veins (nodules?)	fine grained clay minerals	S_s = 87–94 m^2/g; LL = 73–75; PL = 34–36	0.2	0.14	Kaolinite: ~0.1–1 μm
	10	58.44	1107.44	veins		ϕ10 = 9.28; ϕ50 = 6.08	1.6	1.12	
Cascadia Margin	11	3.7	678.2	nodules	soft clay sediments	ϕ50 = 5.7; S = 1.2; Sk = −0.81(at 3.59 m)	4	0.3	
	12	13.05	687.55	nodules		ϕ50 = 4.05; S = 0.95; Sk = −0.58	2.5	0.2	
Offshore Peru	13	141	3961	nodules	diatomaceous muds (44%Illite)		0.01	0.01	Illite: ~10–100 nm
	14	165.6	5235.6	nodules	diatomaceous muds	ϕ10 = 5–6	23	8	
Okushiri Ridge	15	88.3–97.9	2715.7	pore filling	Sandy sediments		100	70.13	fine/medium sands: 0.06–0.6 mm
	16	88.3–97.9	2715.7	nodule	diatom-bearing clays, silty clay	LL = 113–143 (at 83.75–189.9 m, 799A)	0.01	0.01	Illite: ~10–100 nm
	17	91.07	2661.67	nodule	abundant diatoms	75% sand + 15% silt + 10%clay	0.2	0.1	Kaolinite: ~0.1–1 μm
Ulleung Basin	18	136	2100	veins/lenses	microfossile, clay	d_{50} = 3.041 μm; d_{10} = 1.5 μm	1.5	1.05	
	19	140	2218	vein and nodule		18%clay + 82%silt S_s = 71 (at 141 m)	0.2	0.14	Kaolinite: ~0.1–1 μm
Orca Basin, GOM	20	20–40	2425	nodules	smectite dominant clay	LL = 83; PL = 31	0.001	0.0007	Smectite ~1 nm
Alaminos Canyon, GOM	21	~400	~3130	pore filling	fine sands		80	56.10	fine sands: 60–200 μm
Sea of Okhotsk	22	2.3–2.7	~840	nodules	20.42% clay	ϕ50 = 6.13; S = 1.73; Sk = 1.4; Kt = 2.16	0.45	0.25	
	23	1.65–2.65	~670	nodules/veins	23.4% clay	ϕ50 = 6.35; S = 1.70; Sk = 1.31; Kt = 2.09	0.4	0.2	
Mt. Elbert	24	619.9	619.9	pore filling	fine quartz sand	d_{10} = ~0.2 mm (at 618.1 m)	200	140.26	
	25	661	661	pore filling	fine-grained quarts	d_{10} = ~0.08 mm (at 662.4 m)	80	56.10	
	26	620	620	vein	silty sand	d_{10} = 0.017 mm	17	11.92	

Dai et al. (2012)

Morphologie



Dai et al. (2012)

Formation d'hydrates en laboratoire

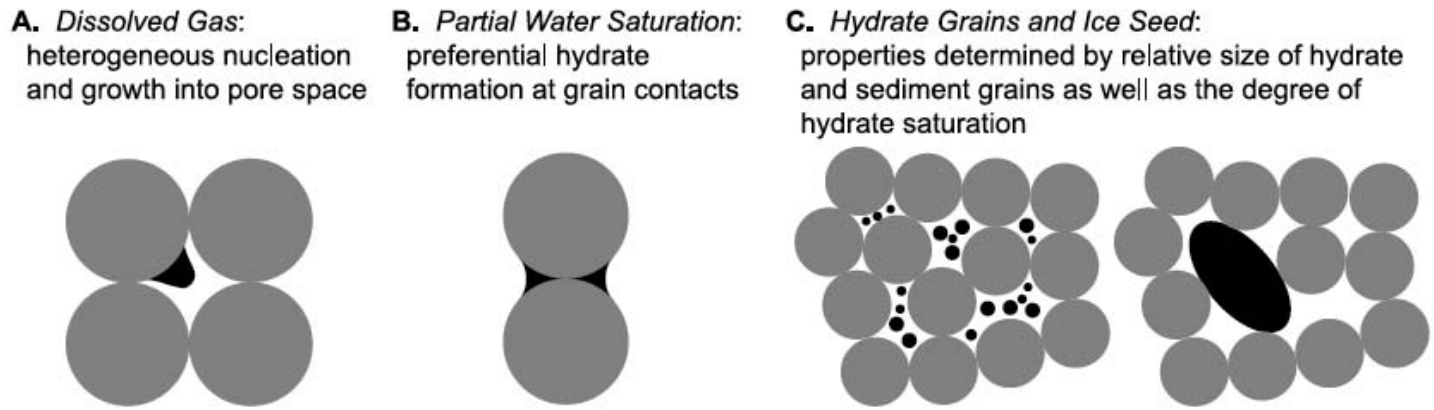
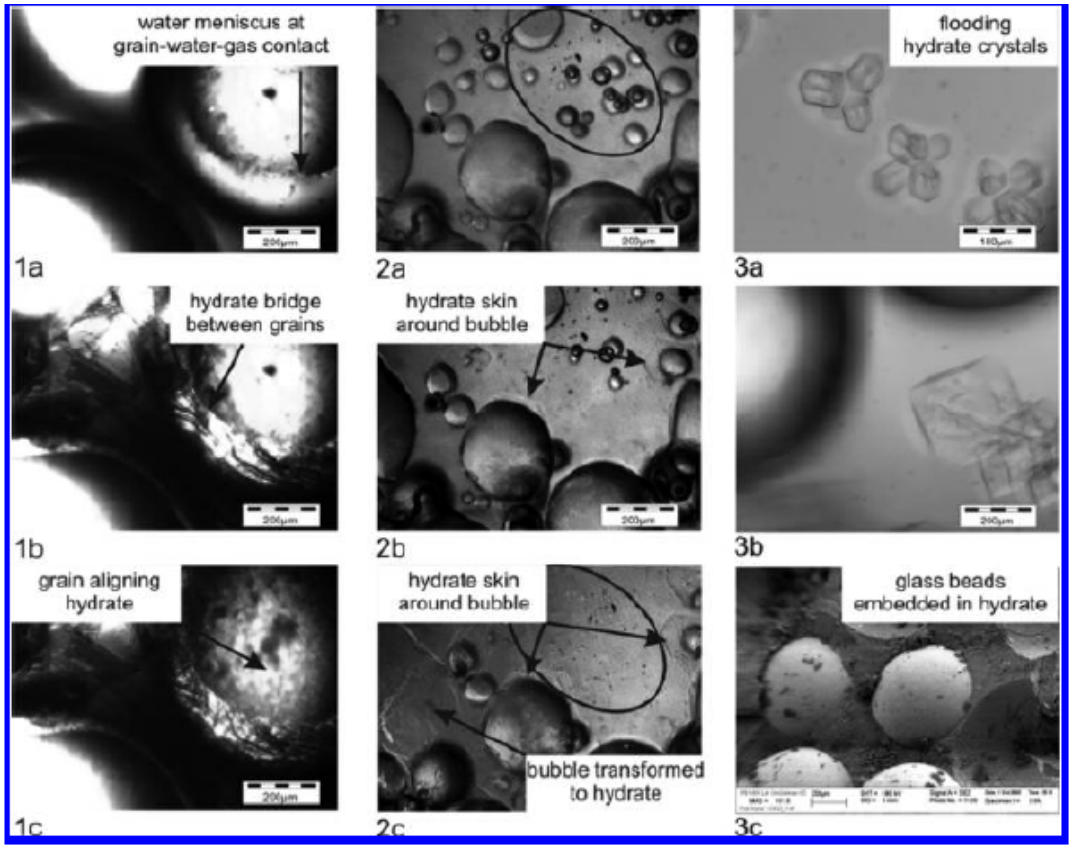


Figure 3. Dependence of hydrate habit on hydrate formation technique. Physical properties of hydrate-bearing sediments depend on the size and distribution of hydrate (black) relative to the sediment grains (gray).

Waite et al. (2009)

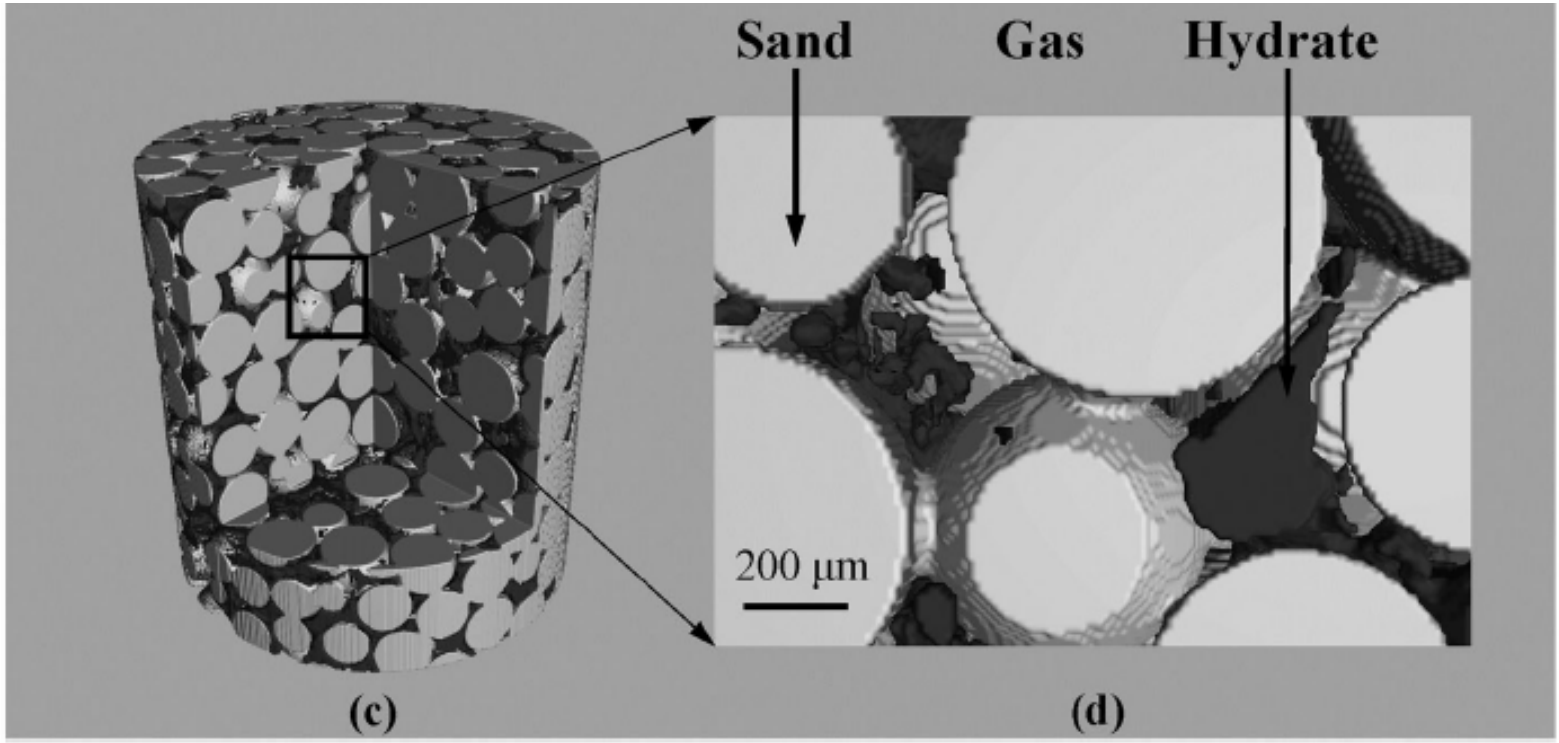
Microscopie



Spangengerg et al., 2015

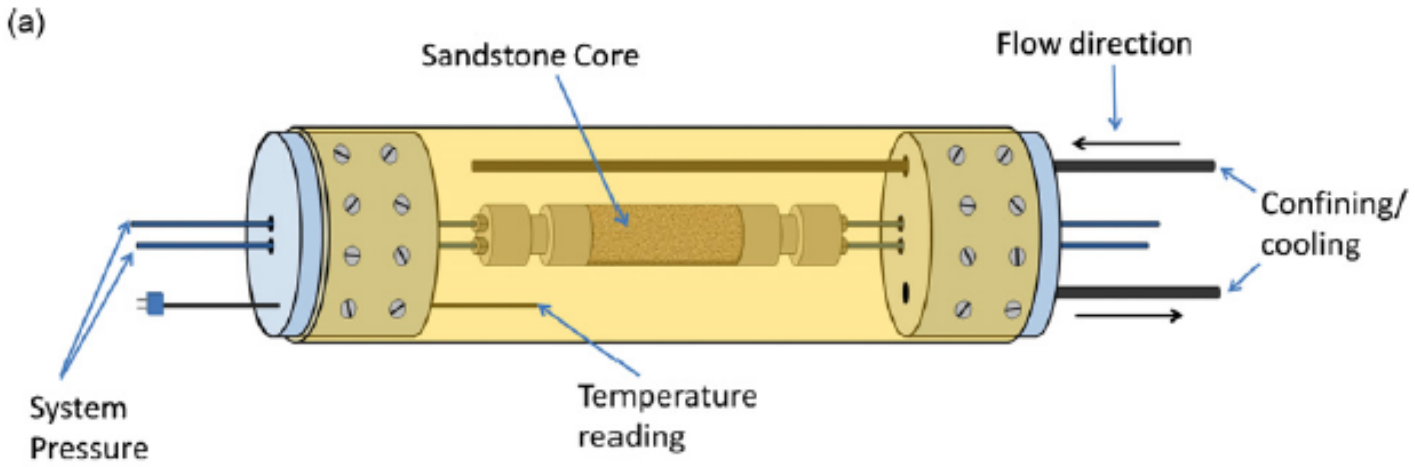
Figure 4. Images of hydrate growing from water and free methane gas (panels 1 and 2) and from methane dissolved in water (panels 3). The procedure to gain these photographs is described in detail in Spangenberg et al.[47] (1a) Glass beads, water, and methane situated outside the hydrate stability. (1b) Hydrate growing at the gas–water interface forming a bridge between neighboring grains. (1c) Water, wetting the glass beads is finally transformed into hydrate and the grain surface is covered with grain aligning hydrate. (2a) Methane bubbles in water outside the hydrate stability field. (2b) Within the hydrate stability field hydrate starts to form around the bubbles. (2c) Large bubbles are transformed to hydrate (some with a gas inclusion inside), whereas smaller bubbles disappear due to dissolution and hydrate formation (see ellipse in panels 2a and 2b). (3a) Hydrate formed from methane dissolved in water without a free-gas phase crystallizes in the pore water. (3b) To date there is no evidence that hydrate crystals grow at grain surfaces. We could only observe hydrate flooding in the pore water. (3c) An SEM-image of glass beads embedded in a matrix of almost pure methane hydrate (ice to hydrate ratio is 17 % to 83 %).[15]

Microtomograph aux rayons X



Zhao et al (2015)

IRM



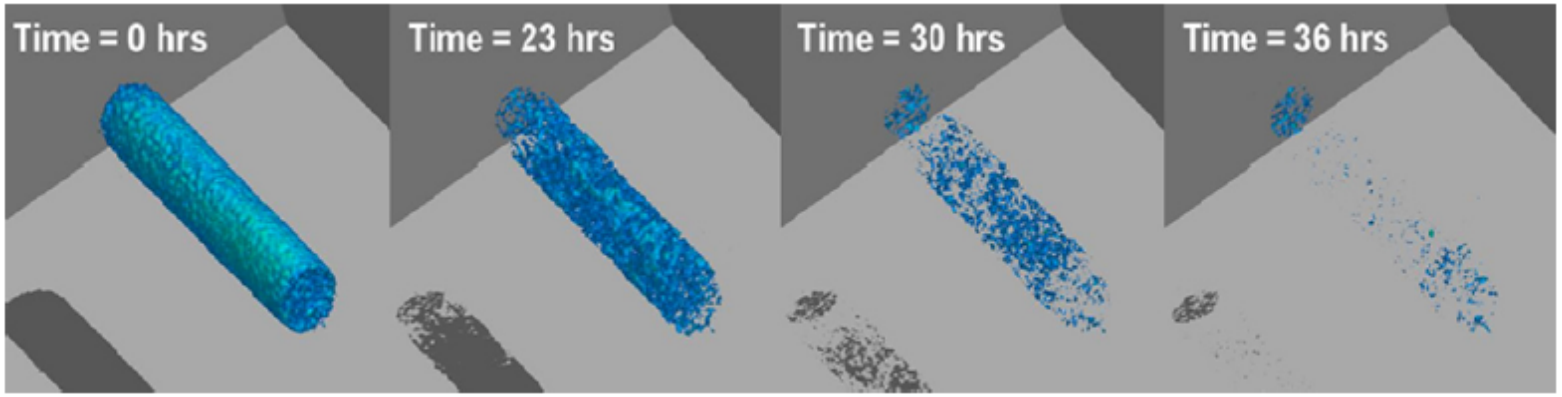
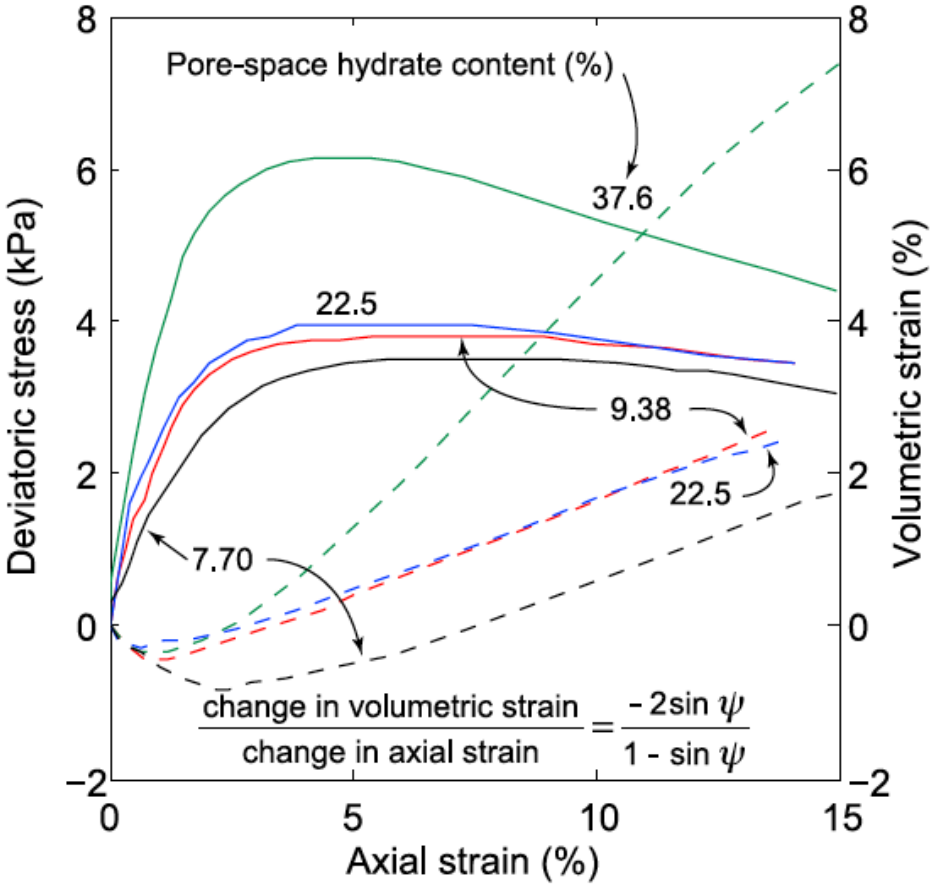
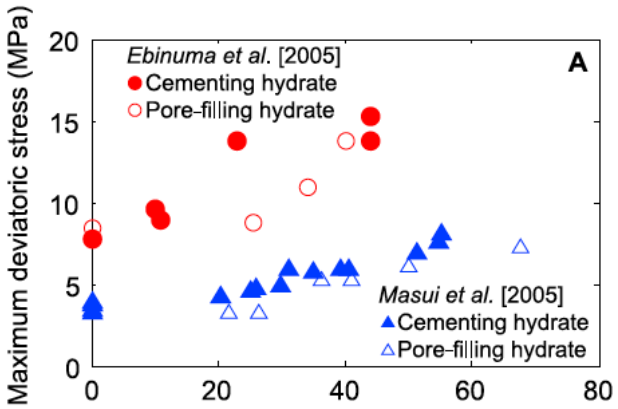


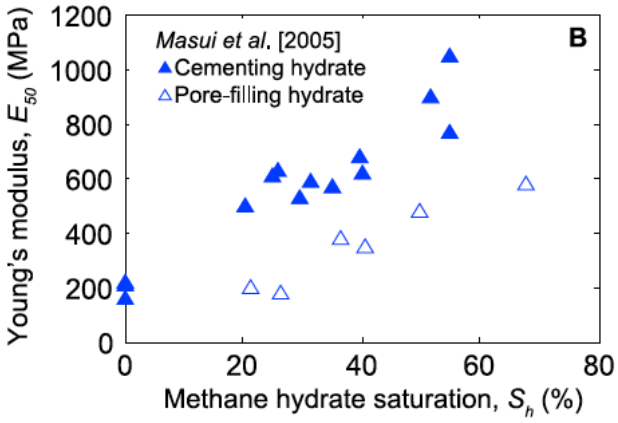
Fig. 4. Hydrate formation in whole core [3].

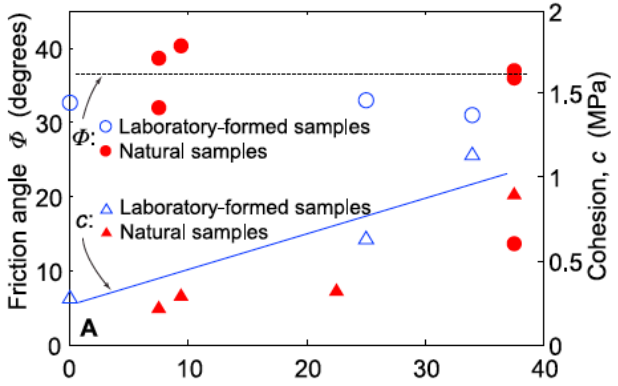
Ersland et al (2010)

Essai triaxial





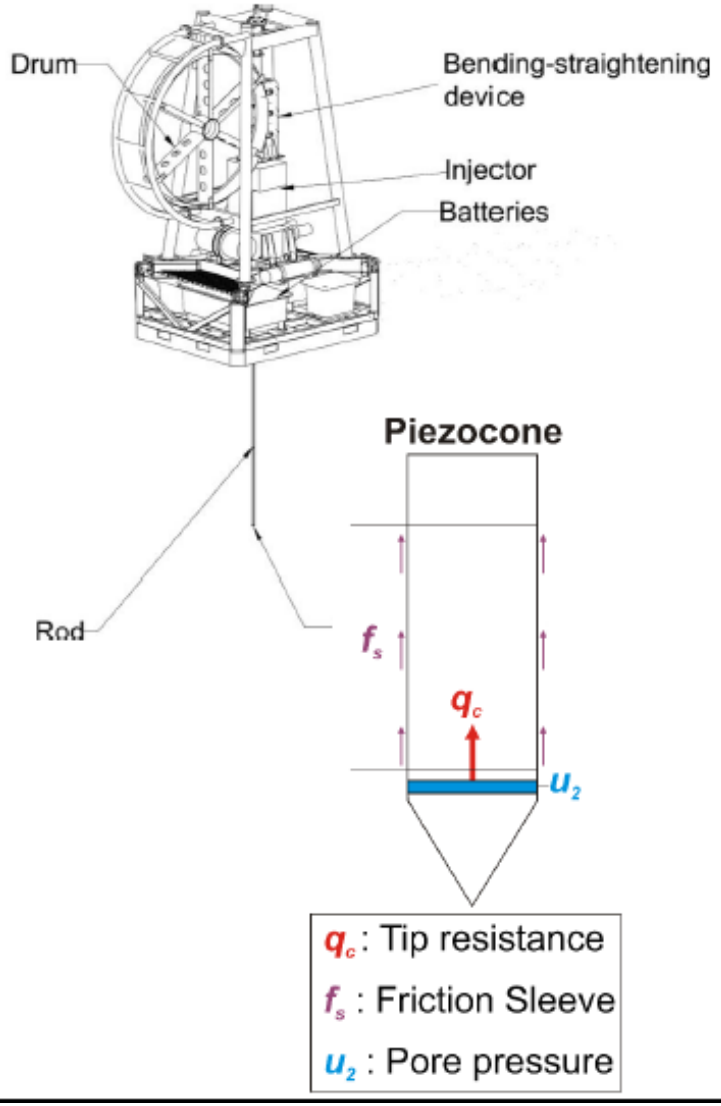




Waite et al (2009)

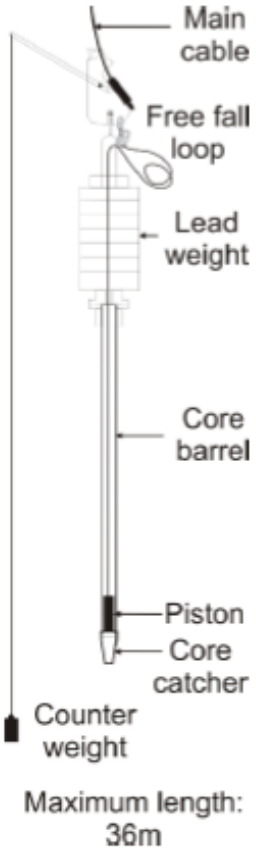
Mesures in situ

Penfeld penetrometer



q_c : Tip resistance
f_s : Friction Sleeve
u_2 : Pore pressure

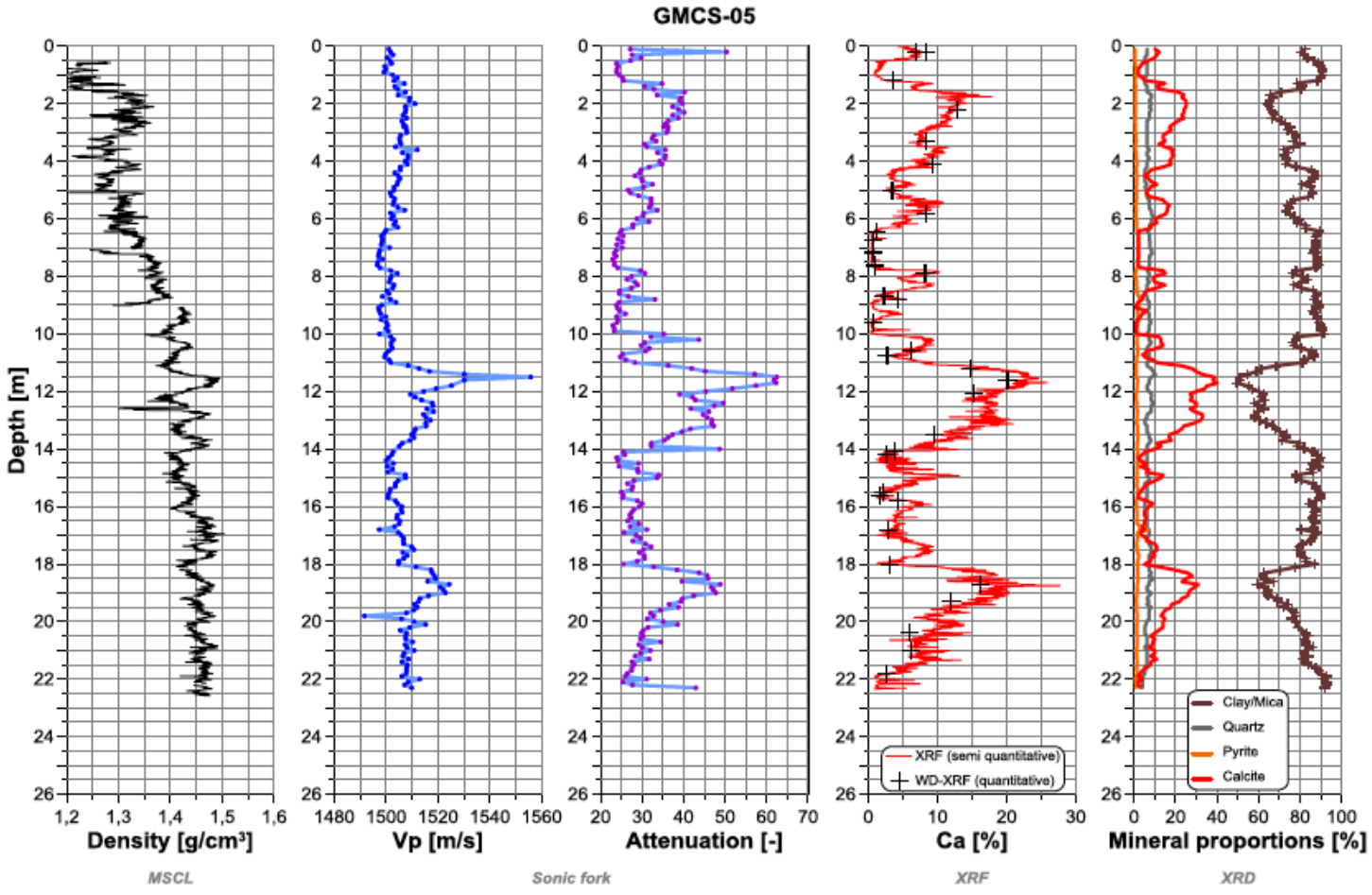
Calypso piston corer



Maximum length: 36m

Mesures in situ vs laboratoire

Analyse de mesures in situ et en laboratoire pour déterminer la quantité d'hydrates de gaz



Etablir un modèle pétrophysique

Modélisation par éléments discrets

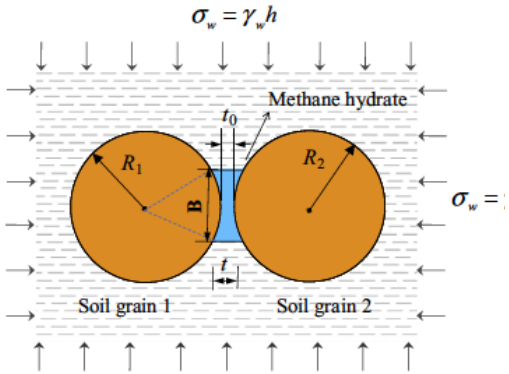
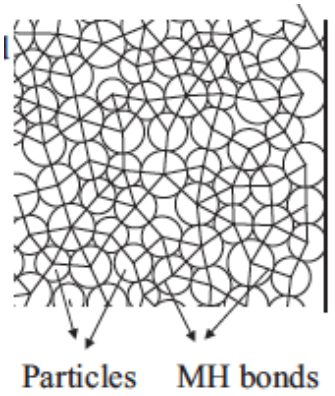
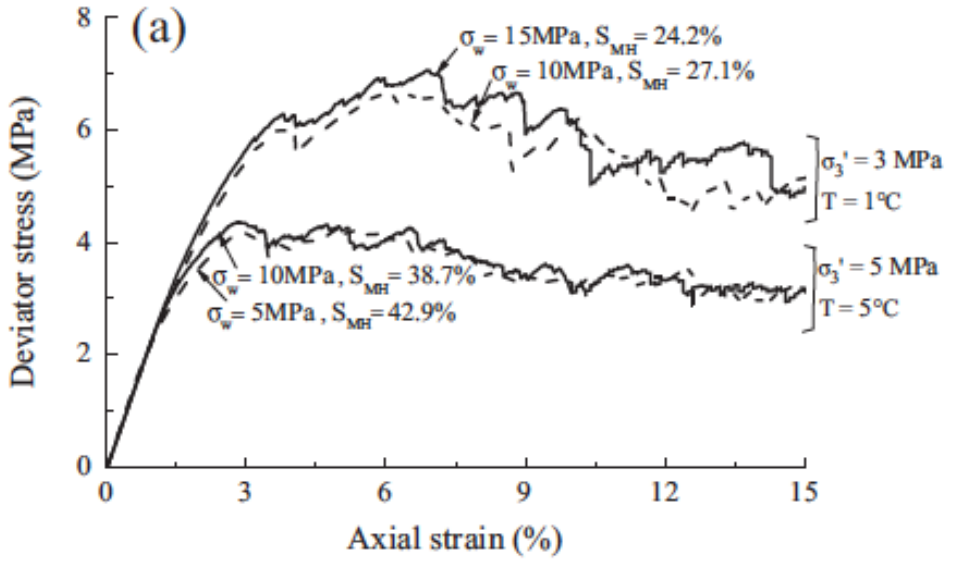
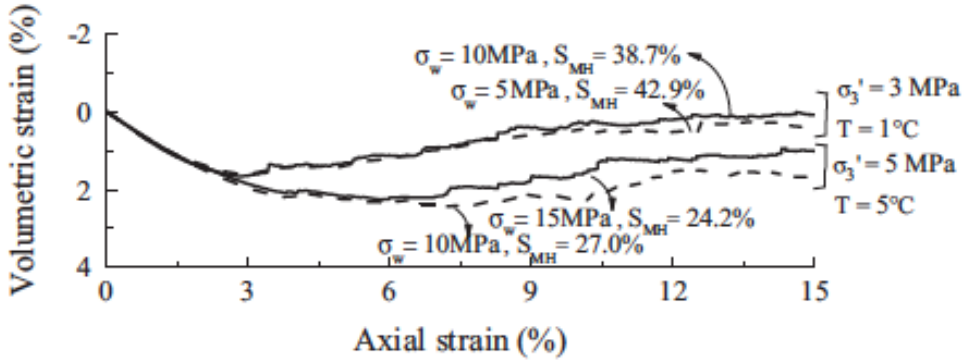


Fig. 3. A pair of soil grains immersed in water and cemented b

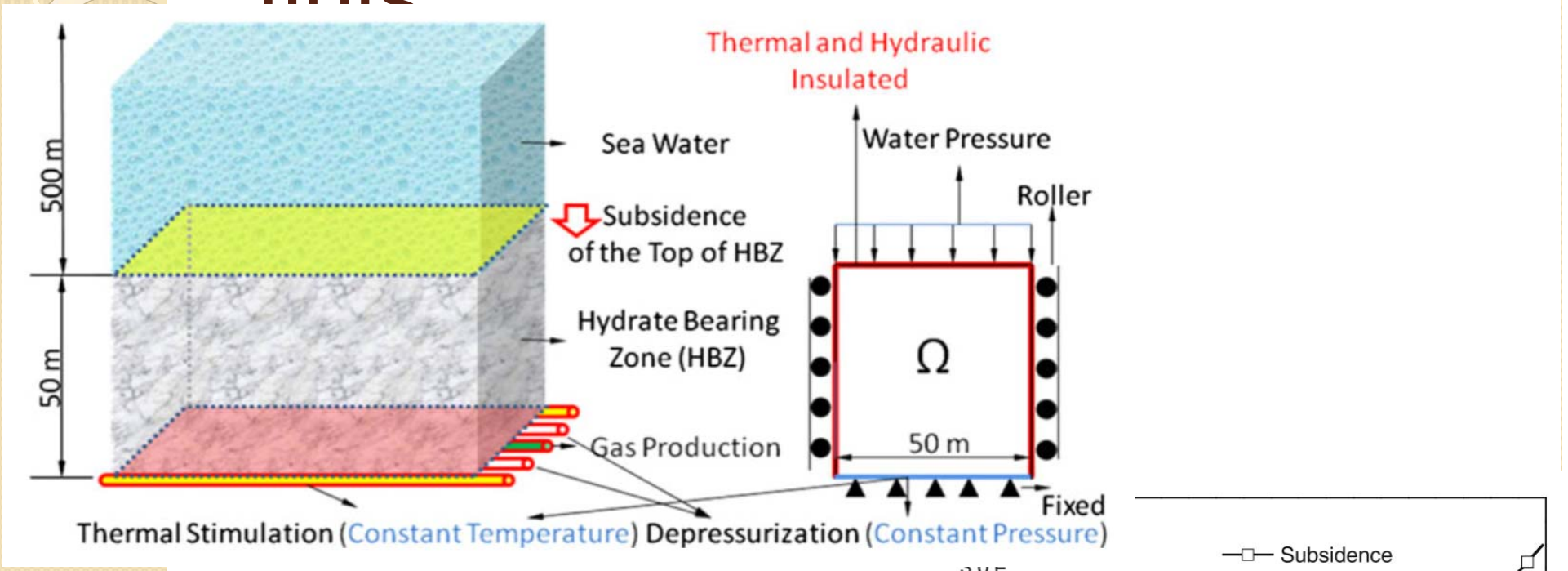


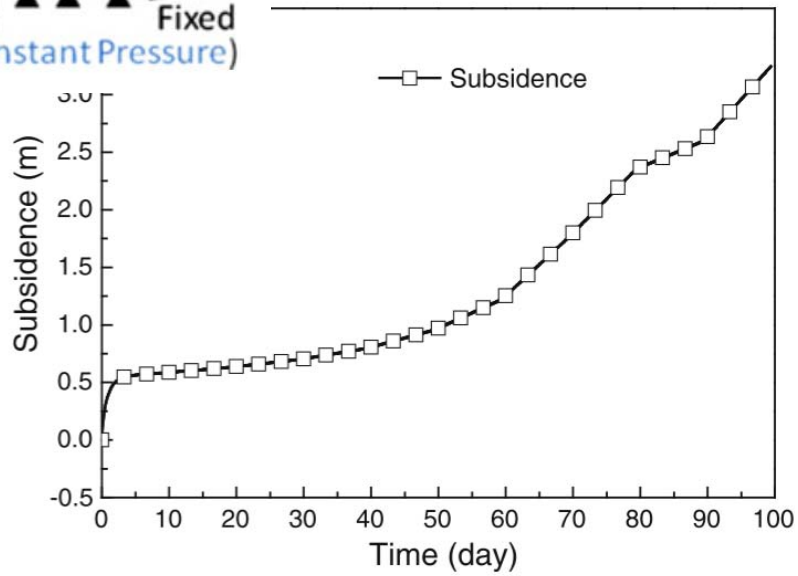




Jiang et al (2015)

Modélisation par éléments finis





Liu & Yu (2013)

Retombées attendues

- **Scientifiques**: Formation/dissociation hydrates; Effet des hydrates; Détection in situ; Appréhension de risques; Publications, séminaire.
- **Techniques**: Observations optiques; Système de contrôle de température/pression pour dispositifs existants; Modèles constitutifs macroscopiques; Code de calcul numérique; Méthode de mesure in situ; Gestion de projet.
- **Economiques**: Avancées dan l'exploitation des hydrates de gaz comme sources d'énergie; Stockage CO2 (formation des hydrates de CO2); Prédiction du dégagement de gaz à effet de serre (dissociation des hydrates; Autres domaines technologiques basés sur les hydrates

Participants

Partner	Surname	First name	Role and sphere of responsibility for the project
ENPC	TANG	Anh Minh	*Thermo-hydro-mechanical experiments*
UPPA	BROSETA	Daniel	*Formation and dissociation of gas hydrates at the pore scale*
ENPC	PEREIRA	Jean-Michel	*Numerical modelling by Finite Element Method*
IFREMER	GARZIGLIA	Sebastien	*Analysis of in situ data*
UPPA	BOURIAT	Patrick	*Emulsion and colloidal behaviour*
UPPA	BROWN	Ross	*Optical microscopy*
ENPC	BORNERT	Michel	*X-ray micro-tomography*
ENPC	AIMEDIEU	Patrick	*X-ray micro-tomography*
ENPC	RODTS	Stéphane	*Magnetic Resonance Imaging*
ENPC	ROUX	Jean-Noël	*Discrete Element Method*
ENPC	DANGLA	Patrick	*Physicochemical couplings in porous media*
IFREMER	SULTAN	Nabil	*Analysis of in situ data*

Merci de votre attention!

Anh Minh TANG
Ecole des Ponts ParisTech
anhminh.tang@enpc.fr