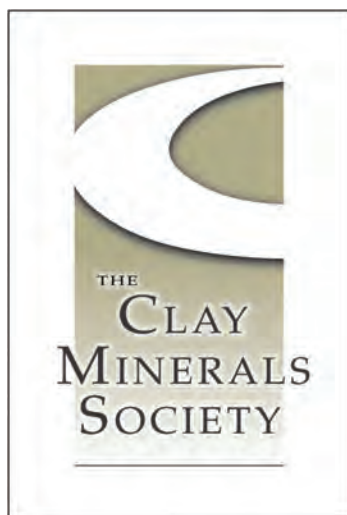


CMS WORKSHOP LECTURES

Volume 22

**INTRODUCTION TO
OIL SANDS CLAYS**



THE CLAY MINERALS SOCIETY

Joseph W. Stucki, Series Editor and Editor in Chief
University of Illinois
Urbana, IL 61801-4798, USA

Oladipo Omotoso¹ and Daryl Hockley²

¹ Suncor Energy, Calgary, AB, Canada, and ² SRK Consulting (Canada) Inc.

CMS WORKSHOP LECTURES

VOLUME 22

INTRODUCTION TO OIL SANDS CLAYS

Organized By

Daryl Hockley
SRK Consulting (Canada) Inc.

Oladipo Omotoso
Suncor Energy, Calgary, AB, Canada

Heather Kaminsky
NAIT Applied Research, Edmonton, AB, Canada

Contributors

Daryl Hockley, SRK Consulting (Canada) Inc.

Oladipo Omotoso, Suncor Energy, Calgary, AB, Canada

Patrick H.J. Mercier, National Research Council, Ottawa, Ontario, Canada

Cliff T. Johnston, Bindley Bioscience Center, 1203 W. State Street, Purdue University, West Lafayette, IN 47907-2057, USA

Andrew Vietti, Vietti Slurrytec, Johannesburg, South Africa

Heather A. Kaminsky, NAIT Applied Research, Centre for Oil Sands Sustainability, Edmonton, AB, Canada

Elco Hollander, Suncor Energy, Inc. Calgary, Alberta. T2P 3E3, Canada

Randy Mikula, Kalium Research, Edmonton, Alberta, Canada

Published by

The Clay Minerals Society
3635 Concorde Pkwy Suite 500
Chantilly, VA 20151-1125, USA

Copyright © 2018 The Clay Minerals Society

All rights reserved. No part of this book may be reproduced by any mechanical, photographic, or electronic process or in the form of photographic recording, nor may it be stored in a retrieval system, transmitted, or otherwise copied for public or private use without written permission from the publisher. For information on this and other volumes in the CMS Workshop Lectures Series, write The Clay Minerals Society, 3635 Concorde Pkwy Suite 500, Chantilly, VA 20151-1125 USA or go to www.clays.org.

Citations of articles in this volume are properly referenced as follows:

Mercier, P.H.J., Omotoso, O., and Hockley, D. (2018) Oil-sands clays. Pp. 9–32 in: *Introduction to Oil Sands Clays* (O. Omotoso and D. Hockley, editors). CMS Workshop Lectures, **22**. The Clay Minerals Society, Chantilly, Virginia, USA.

Library of Congress Catalog Number

ISBN: 978-1-881208-48-8

THE CLAY MINERALS SOCIETY

The Clay Minerals Society (CMS) was organized in 1963 to stimulate research and to disseminate information relating to all aspects of the science and technology of clays and other fine-grained minerals. It sponsors an annual Clay Conference where research and invited papers are presented in technical sessions and special symposia. Field trips are organized to important occurrences of clays in regions near the Conference locations and to industrial sites of clay production and application. In conjunction with its annual meetings, workshops are held on technical subjects of interest to clay researchers and technologists. CMS publishes *Clays and Clay Minerals*, which is the leading international journal in the field of clay science. In this journal are presented the latest scientific investigations in all areas of the field and from all parts of the world, along with timely review articles and announcements of new publications on clays and other fine-grained minerals.

The CMS also sponsors the Source Clays Repository which is now well established as the provider of clay samples to a plethora of research groups worldwide and to teachers of clay science. The Society also offers other clay-related publications to its members at a discount over the publisher's list prices.

Its multi-disciplinary membership includes agronomists, microbiologists, surface chemists, physicists, geologists, mineralogists, geochemists, material scientists, soil scientists, crystallographers, sedimentologists, economic geologists, colloid chemists, ceramicists, rheologists, petroleum engineers, and geotechnical engineers, thereby offering members the opportunity to exchange ideas and results with fellow researchers having widely different backgrounds and expertise.

For information on joining the Society and subscribing to *Clays and Clay Minerals*, contact:

The Clay Minerals Society
Society Office
3635 Concorde Pkwy Suite 500
Chantilly, VA 20151-1125
USA

Phone: (703) 652-9960

FAX: (703) 652-9951

www.clays.org

E-mail: cms@clays.org

Contents

Chapter 1. Introduction	1
by DARYL HOCKLEY and OLADIPO OMOTOSO	
1. Why Clay in Oil Sands?	1
2. Fundamentals	1
3. Applications	4
4. Limitations	6
Acknowledgements.....	7
References.....	7
Chapter 2. Oil-sands clays	9
by PATRICK H.J. MERCIER, OLADIPO OMOTOSO, and DARYL HOCKLEY	
1. Clays and clay minerals overview	9
1.1. Definitions of the terms ‘clay’ and ‘clay mineral’	9
1.2. Background on structure and crystal chemistry of phyllosilicates	10
1.3. Centrifugation method for separating specific particle-size fractions	18
2. Geology of Athabasca oil sands with emphasis on McMurray formation and its associated clay mineralogy distribution	20
2.1. Geology.....	20
2.2. Clay mineralogy of the oil-sands deposits.....	22
2.3. Non-phyllosilicate phases associated with oil sands	24
3. Mineral deportment in the extraction process	24
3.1. Fluid fine tailings (FFT) mineral composition.....	25
3.2. Froth treatment tailings (FTT) mineral composition	26
References.....	28
Chapter 3. Surface chemistry of oil-sands clay minerals.....	33
by CLIFF T. JOHNSTON	
1. Introduction	33
2. Surface atoms	34
3. Chemical bonds	37
4. Surface structures and properties	38
4.1. Neutral siloxane surface	38
4.2. Hydroxyl surface	39
4.3. Broken-edge sites	41
4.4. Isomorphous substitution sites	42
5. Water interactions with clay surfaces	45
6. Clay–organic interactions	49
6.1. Organic-rich solids	49
6.2. Naphthenic acids and volatile organic carbon compounds	51

6.3. Polymer flocculants in tailing applications	51
6.4. Methylene blue	52
References.....	53

Chapter 4. Clay–water interactions.....61

by **ANDREW VIETTI**

1. Introduction	61
2. Colloidal theory and particle interaction	61
2.1. Surface charge/potential	62
2.2. Diffuse layer thickness	63
2.3. Particle interactions	64
3. Clay–water interactions	65
3.1. Oil-sands clays	65
3.2. Process water quality	66
3.3. Dispersion, coagulation, flocculation, and gelation.....	67
4. Criteria for predicting colloidal effects.....	68
4.1. CEC, ESP, and SAR.....	69
4.2. Slurry pH	70
4.3. Slurry ionic strength.....	72
4.4. Example: colloidal effects in tailings dewatering	72
References.....	74

Chapter 5. Clay measurement methods in oil sands75

by **HEATHER A. KAMINSKY, and OLADIPO OMOTOSO**

1. Introduction	75
2. Methods for measuring fine particle sizes	76
3. Direct clay-size measurement	76
3.1. Electron microscopy.....	76
3.2. Coherent scattering domains	77
3.3. Methylene Blue adsorption	77
4. Indirect clay-size measurements	79
4.1. Sedimentation methods.....	79
4.2. Laser diffraction	81
5. Clay mineralogy	83
5.1. X-ray powder diffraction (XRD)	84
5.2. Transmission electron microscopy.....	86
6. Online clay measurements.....	87
6.1. Near-infrared spectroscopy (NIR)	87
6.2. K-40 Gamma spectrometry	87
6.3. Dielectric spectroscopy.....	88
References.....	88

Chapter 6. Mescoscale phenomena.....91
by **DARYL HOCKLEY**

1. Introduction	91
2. Introduction to physical processes	92
2.1. Stokes' Law of flotation and settling	92
2.2. Hindered settling.....	93
2.3. Consolidation and strength gain.....	93
3. Interface properties	94
4. Slurry rheology	95
4.1. Effects on Stokes flotation/settling	98
4.2. Effects on pipeline design	98
4.3. Effects on fluid fine tailings	99
5. Hydraulic conductivity	100
5.1. Effect of clay on hydraulic conductivity of oil-sands tailings	101
5.2. Hindered settling function and thickening.....	102
5.3. Equivalent concepts in other applications	103
6. Matrix strength	103
6.1. Compressibility of oil sands tailings	104
6.2. Equivalent concepts in other applications	105
6.3. 'Slurry to soil' transition	105
6.4. Development of shear strength in fluid fine tailings	106
References.....	106

Chapter 7. Clays impact on bitumen-extraction processes109
by **ELCO HOLLANDER, and DIPO OMOTOSO**

1. Introduction	109
2. Literature overview on the role of clay minerals in extraction	111
3. An operations view of bitumen extraction	112
3.1. Some relevant dimensionless groups	113
3.2. Hydrotransport (mixing).....	114
3.3. Aeration kinetics.....	116
3.4. Flow-field evaluation	120
3.5. Bitumen-froth separation	123
3.6. Process response to upset conditions	125
4. Summary	125
References.....	126

**Chapter 8. The role of clays in the performance of oil-sands tailings
management options.....129**
by **RANDY MIKULA**

1. Introduction	129
-----------------------	-----

2. The distribution of clays in oil-sands tailings.....	133
2.1. Oil-sands clay minerals and water-holding capacity	134
2.2. Clays vs. fines in tailings characterization.....	137
3. Clay to water ratio as the parameter in defining tailings management performance	138
4. The evolution of tailings management in surface-mined oil sands	140
4.1. Tailings ponds and the accumulation of mature fine tailings	140
4.1.1. Predicting mud line and recycle water availability in tailings ponds.....	141
4.1.2. MFT characterization, formation, and tailings-pond profiles.....	144
5. Tailings-management options in surface-mined oil sands	145
5.1. The non-segregating, composite, or consolidated tailings process	146
5.1.1. Clay content as the defining CT performance criterion	149
5.1.2. Controlling water chemistry with clays	153
5.1.3. Carbon dioxide as a CT/NST process additive	155
5.2. Paste or thickened tailings	157
5.2.1. Flocculant selection	157
5.2.2. Thickener performance and Franken fines	158
5.3. Filtered tailings	160
5.3.1. Laboratory experience with filtration	160
5.4. Rim ditching	161
5.4.1. The importance of mixing in polymer and clay systems	164
5.5. Thin lift dewatering: the TRO and AFD processes.....	166
5.5.1. Clay content and dewatering performance	167
5.6. Centrifuged fluid fine tailings.....	168
5.6.1. Evolution of the centrifuge technology	169
5.6.2. Centrifuge performance based on clay content	171
6. Summary	173
7. Glossary of terms.....	174
Acknowledgments	177
References.....	178

Chapter 9. Clay effects on geotechnical properties of tailings 183
by **DARYL HOCKLEY**

1. Introduction	183
2. Oil-sands tailings, fluid fine tailings, and clay	183
3. Oil-sands tailings deposit types.....	185
3.1. Deposit types	185
3.2. 2016 fluid tailings management plans	187
4. Effects of clay on geotechnical properties of tailings deposits and processes	187
4.1. Index properties	187
4.2. Hydraulic conductivity	191

4.3. Compressibility	195
4.4. Shear strength	200
4.5. Examples.....	205
5. Other processes affecting tailings deposits	208
References.....	209