A Report of 9th International Methane Hydrates R&D Workshop "Science & Technology of Gas Hydrates: When can they be produced efficiently and safely"

Kalachand Sain, Md. Rafique, Satendra Singh & Harsh Gupta

CSIR-National Geophysical Research Institute, Uppal Road, Hyderabad -7

Email: kalachandsain@yahoo.com

The 9th **International Methane Hydrates R&D (Fiery Ice 2014) Workshop** was held at Hyderabad International Convention Centre (HICC), **organized by the CSIR-National Geophysical Research Institute, Hyderabad during November 10-12, 2014 on the theme "Science & Technology of Gas Hydrates: When can they be produced efficiently and safely"**. The present workshop, steered by an International Committee and advised by a Local Organizing Committee under the chairmanship of Prof. Harsh Gupta, President of International Union of Geodesy & Geophysics provided a platform for deliberation, interaction, sharing information on leading edge topics: natural systems, energy potential, environmental issues, advancement in production ... by an outstanding and diverse group of researchers/scientists from both the academia & industries, and fostered an opportunity for International Collaboration. **The workshop was preceded by a 'Geologic Field Excursion' to Nagarjuna Sagar** on November 9, 2014 in which 33 delegates participated and **followed by a 'Laboratory Visit' to CSIR-National Geophysical Research Institute on November 13, 2014** in which 20 delegates participated. A total of 106 (32 International and 74 National) delegates took part in the workshop. At the end of the workshop in the evening of 12th November, 38 delegates visited 'Golconda Fort - A Historical Place'.

The workshop consisted of 2 Keynote Lectures, Presentation of **10 National Reports** and **46 Individual Research Papers** with 16 Oral and 30 Posters, and **6 Break-out Sessions**.

The inaugural session of the Workshop was chaired by Prof. Harsh Gupta, and the workshop was inaugurated by Mr. S.K. Srivastava, Chairman and Managing Director of Oil India Limited. The very presence of these two personalities, former occupying the top position in oil industries and the latter being the architect of Indian Gas Hydrates Program under the Ministry of Earth Sciences (the then Department of Ocean Development), show their concern on gas hydrates program in India. During remarks, **Prof. Harsh Gupta**, based on his experience by attending many international meetings/conferences, **stressed on the need to expose/project gas-hydrates program to the Earth Science community**, to exchange knowledge/idea through collaboration, particularly among the researchers in the energy-starving Asian countries, and to best exploit the advantages of this expensive research and development (R&D). **Mr. S.K. Srivastava pointed out that India is now looking for sand dominated gas-hydrates reservoir in the Krishna-Godavari and Mahanadi offshore basins during the second expedition of Indian National Gas Hydrates Program (NGHP)**. Mr. Srivastava earlier held the position of Director General of Directorate General of Hydrocarbons (DGH) that manages and coordinates the activities of NGHP. During the first expedition in 2006, massive gas-hydrates were recovered in fractured shale that may not be producible economically. Prof. Richard Coffin of Texas A&M University, USA outlined the concept of IMHRD Workshop, which was held earlier in USA, Chile, Canada, Scotland, Norway, New Zealand and Japan. Dr. Jiro Nagao summarized the outcome of the 8th IMHRD Workshop held in Japan in 2012.

The key note speeches provided global overview on the exploration and exploitation status of gas-hydrates. The individual oral and poster presentations demonstrated recent results/ discoveries based on theoretical development and applied research. The abstracts of these presentations can be found in www.fieryice2014.org.

Prof. Richard Coffin of Texas A&M University, USA **showed that methane hydrates are being investigated globally for better understanding of climate change, coastal stability and most importantly for harnessing as future major energy resource**. There are strong efforts in methane hydrate exploration and energy assessment by teams of scientists and industry people off the coasts of Japan, India, China, Korea, Taiwan and many other nations. He presented some geophysical, geological and geochemical data sets from the Gulf of Mexico, Mid Chilean Margin, Mackenzie Delta and Prudhoe Bay, Arctic Ocean and two regions off the coast of New Zealand.

Prof. Bjorn Kvamme of the University of Bergen, Norway **talked on the feasibility of simultaneous carbon dioxide storage and methane production from natural gas hydrate (NGH) reservoir using a mixture of carbon dioxide and nitrogen**. The use of carbon dioxide mixed with nitrogen has the advantage of higher gas permeability and less tendency for blocking flow channels. This concept has been verified experimentally and theoretically in different laboratories worldwide, and lately also through a pilot plant in Alaska.

Mr. S.K. Srivastava lighting the Lamp during the Inauguration of the 9th IMHRD Workshop.
Prof. Bjorn Kvamme and Dr. Richard Coffin look on.

Prof. Harsh Gupta during his remarks at the Inauguration of the 9th IMHRD Workshop

The National Reports of 10 countries were presented and briefed below. This **offered latest activities and progress of gas-hydrate R&D in respective countries** and scope for International collaboration.

Dr. Jiro Nagao of National Institute of Advanced Industrial Science and Technology (AIST) of Japan, **while presenting the Recent Progress of the Methane Hydrate R&D Program in Japan, mentioned that NGH would become a valuable domestic energy resource once its production technique is established**. Japan has attempted in March, 2013 the world's first extraction of methane gas from offshore NGH deposits. This field test was performed in the eastern Nankai Trough with main objectives of i) confirmation of gas productivity form marine hydrates, ii) evaluation of stability and integrity of wells for shallow and unconsolidated sediments, and iii) implementation of monitoring technologies for methane hydrate dissociation behaviour. **Stable depressurization and flow of gas and water for six days with respective production rates of ~ 20000 Sm3/day and 200 m3/day clearly indicate that depressurization method appears to be a cost-effective solution for producing methane from marine gas hydrates reservoir**.

Prof. Werner F. Kuhs of Georg-August-Universität Göttingen, Germany **presented the German Gas Hydrate Initiative SUGAR** (SUbmarine GAs hydrate Reservoirs) **from Exploration to Exploitation**. The technologies developed in SUGAR includes the state-of-the-art hydro-acoustic, 3-D seismic and electromagnetic devices for exploration as well as monitoring of exploitation operations, new autoclave systems for mobile drilling rigs (MeBo 70 and 200) recovering marine hydrates under in situ pressure. **The primary focus is on the production of methane with the safe sequestration of CO_2 in methane hydrates reservoir below the seafloor**.

Dr. Jong-Hwa Chun of Korea Institute of Geoscience and Mineral Resources (KIGAM) presented the Korean gas hydrate program that consists of Phase 1 (2005–2007) - exploration and initial drilling; Phase 2 (2008–2011) - reserve assessment, applicable basic production technology and subsequent drilling; and Phase 3 (2012–2016) - development of optimal production technology and test production. The **KIGAM conducted two drilling expeditions (2007-UBGH 1 and 2010-UBGH2) in the Ulleung Basin, East Sea of Korea that characterized the gas hydrate reservoirs and assessed the resources based on 2D & 3D seismic data. Korea also developed test production technologies and conducted an environmental impact assessment of production of hydrates in deep-water Ulleung Basin**.

Zhou Shouwei of China National Offshore Oil Corporation (CNOOC) presented the status of gas hydrates research in China in terms of exploration, experimental facilities, exploitation methods and associated risks. **The CNOOC, for the first time in October 2012 in Qingdao, presented solid fluidization development principle of NGH reservoir in shallow sediments of deepwater, and obtained the patent**. **The core idea of fluidization mining is to change uncontrollable NGH in shallow layers of deepwater into a controllable gas hydrate resources by seabed closed fluidization lifting system**, so as to ensure the safe production.

Praveen Linga of National University of Singapore (NUS), **emphasised on the innovative and promising solution to secure future energy needs and mitigate carbon dioxide emissions simultaneously by replacement of methane trapped into the gas hydrate deposits with carbon dioxide**. The challenges on sand and water management during the production are acute that are required to overcome for sustainable energy production. He summarized the state of the art experimental work in methane production from NGH carried out at NUS and, outlined the future directions and challenges.

Shyam Chand of Geological Survey of Norway presented on '**Fluid flow and gas hydrate formation along Norwegian offshore: Recent results from the SW Barents Sea**'. **Analysis of gravity cores and carbonate crusts collected from different parts of the SW Barents Sea along with seismic data provided interesting results**: i) The pockmarks are dated to have formed a few thousand years after the glaciers retreated from the SW Barents Sea. They were found to be active until recent past although all of them are almost inactive today. ii) The carbonate crusts and fossil expressions of methane seepage from SW Barents Sea reveal a similar age span, indicating that they also started forming after deglaciation. iii) Estimates of extractable organic matter indicate presence of thermogenic components; methane isotopes also indicate fluid flow from deep source rocks. iv) Foraminifera related to microseep activity are observed at different levels of the post glacial sediments indicating fluid flow towards the seafloor. **Gas hydrate modelling incorporating different gas compositions observed in exploration wells indicate a highly varying gas hydrate stability zone in the SW Barents Sea**.

Dr. Richard Coffin of Texas A&M University, USA presented '**A Review of United states methane hydrate energy exploration and research**'. **The Dept. of Energy (DOE) program have explored gas hydrate reservoir potential and intends to evaluate production methods on terrestrial methane hydrate deposits in Alaska. Prior marine investigations, primarily through the DOE-supported Gulf of Mexico Joint Industry Partnership (JIP), confirmed methods for safe drilling in hydrate-bearing sediments** (Leg I expedition in 2005) **and documented the occurrence of high-quality gas hydrate reservoirs in Green Canyon and Walker Ridge** (Leg II

expedition in 2009). The objectives of marine gas hydrate program are to (i) collect a full suite of in-situ measurements and core samples to characterize the physical properties of hydrate reservoir; (ii) assess the potential response to possible production activities; and (iii) further delineate the occurrence and nature of gas hydrates in the U.S. outer continental shelf.

Dr. Gareth Crutchley of GNS Science, New Zealand provided an '**An update on the state of gas hydrates research in New Zealand**', which has gained significant momentum in the last five years in response to increased funding targeting a wide-range of gas hydrate related issues. New Zealand is currently approaching the half-way point of a 6-year, government-funded gas hydrate programme designed to explore the potential of gas hydrate as an alternative energy resource. **The study has been focussed in the Hikurangi margin – New Zealand's premier gas hydrate province with i) high-resolution velocity analysis that are being used to identify localised gas hydrate deposits, ii) hydrate formation modelling using Petromod®, and iii) analysis of double BSRs**. This has provided improved understanding of deep petroleum system beneath gas hydrate deposits and the geological processes that lead to the formation of concentrated hydrate deposits.

Prof. Tsanyao Frank Yang of National Taiwan University delivered on '**Present status and planning of the gas hydrate program of National Energy Program-Phase II** (NEPII) **in Taiwan**'. **The Central Geological Survey of Taiwan launched two 4-year multidisciplinary gas hydrate exploration programs in 2004 in addition to field investigations, phase equilibrium of gas hydrate via experiment, theoretical modelling and molecular simulation studies**. The national program includes six components: i) resource assessment, ii) production and exploitation, iii) safety and sea-floor stability, iv) carbon cycle, v) deep sea bio-diversity and, vi) energy transportation and industrial application. Furthermore, the NEPII in 2014 has established a Geothermal Energy and Gas Hydrate Focus Center to better coordinate the gas hydrate investigation in Taiwan. **Eventually, it has planned to conduct deep drilling to obtain critical information on gas hydrates and to assess their energy potential**.

Dr. Pushpendra Kumar of Oil & Natural Gas Corporation Ltd presented the '**Indian National Gas Hydrate Program (NGHP) – An Update**'. The gas hydrate exploratory research in India is being steered by the Ministry of Petroleum & Natural Gas under NGHP that is managed and coordinated by the Directorate General of Hydrocarbons (DGH) with the participation from several E&P companies and National Institutions. Based on analysis of geo-science data, prospective areas for gas hydrates occurrences were identified along the East and West Coasts of India and in Andaman regions. **The dedicated gas hydrate coring/ drilling/ LWD/ MWD operations were carried out under the NGHP Expedition-01 at 21 sites (39 wells) in 2006, which established gas hydrates in Krishna-Godavari (KG), Mahanadi and Andaman basins**. However, massive gas hydrates were found in fractured shale or clay in KG basin that may not be extractable with current technologies. From 2007 to 2014, about 7000 sq km seismic data has been studied by ONGC and another 1000 sq km seismic data has been studied by DGH, NIO & NGRI, which show areas with good prospects of gas hydrates in sand reservoirs. **NGHP is currently planning for the execution of NGHP Expedition 02 for drilling/coring/logging in KG and Mahanadi basins with establishing hydrates in sand reservoir**.

The breakout sessions with distinct titles, spread over 3-days of Workshop, provided a comprehensive information to understand more on current development and challenges of gas-hydrates research, the synopsis of which is summarized below.

Breakout Session 1: Challenges in producing gas from methane hydrates and when can they be produced efficiently and safely, moderated by Dr. Richard Coffin, Dr. Praveen Linga & Dr. Sudeep N. Punnathanam, and attended by 42 participants.

Synopsis: The right time of production of gas from gas hydrates depends on energy security of a particular country both in terms of availability of natural gas and oil, and other renewable energy resources; type of geological reservoir and its geographical location; and governments' initiatives, and this aspect varies for different countries. Japan is planning to conduct the next round of field tests in 2018. The full-scale commercial production from methane hydrate reservoir may take another ten years (2028) according to an expert in the audience. Due to higher priority in producing gas from shale deposits, the United States is currently behind Japan towards realizing full-scale commercial development. Korea has planned to conduct her first field tests of production in 2016, of course it depends on results of some critical tests and data analysis. India is planning a field test at least at one location in KG basin within the next five years time.

Breakout Session 2: **Resource assessment of methane hydrates and key parameters for drilling**, moderated by Dr. Jun Matsushima & Dr. Uma Shankar, and attended by 16 participants.

Synopsis: Although there are some methods available for the estimation of in-situ methane hydrates (MH), considerable uncertainty remains in assessing the resource potential. The most popular method for the estimation of MH resource is the 'volumetric method' that is described as: MH Resource = Area X Layer Thickness X Net Gross Ratio X Porosity X MH Saturation X Cage Occupation Ratio. Each parameter used in the estimation has a statistical

distribution. The area and layer thickness can be measured from BSR distribution and 2-D/3D velocity information; Net gross ratio from Vp, Vs, resistivity and GR log; Porosity from Neutron and density logs; and MH saturation from velocity, resistivity, NMR+Density (=DMR).

Similarly, there exists some criteria in choosing the drilling location but the methods have not yet been fully developed. Although BSR is the main criterion but its amplitude is significantly influenced by the presence of gas below MH zone and tuning effect arising from thin layers. The velocity is the most robust and useful information that can be derived from classical interval velocity analysis using Dix equation, PSDM and tomography. In clay dominant MH zone, the BSR and velocity information fluctuate due to fractures. This is considered as one of the good indicators. Other good indicators are (i) strong reflector generated at the top of MH zone, (ii) velocity azimuth anisotropy, (iii) resistivity structure derived from CSEM, (iv) seismic attenuation that varies in clay and sand dominant field, and (v) geological interpretation - fan system, channel system etc.

Breakout Session 3: **Methane hydrates system: origin of methane hydrate reservoir**, moderated by Dr. Shyam Chand & Dr. Nittala Satyavani, and attended by 13 participants.

Synopsis: Methane hydrates reservoir is found in shallow sediments of outer continental margin and permafrost regions, and are mostly confined to the stratigraphic boundaries that are intercepted by structural traps. There may be gas seepage when stratigraphic boundary cross-cuts the ocean floor. Faults are the most promising reservoirs as they facilitate the movement of free gas into hydrate stability zone, as it does not need any additional pressure difference. However, hydrates have been found in finely disseminated form in pore spaces in sandy environment (Blake Ridge) as well as in fracture environment (Gulf of Mexico, Krishna Godavari offshore basin). Whereas in sediments without any fractures, gas will flow by a process called diffusion that takes longer time. Therefore, supply of methane should be optimal for the formation of gas hydrates. Too much of gas may cause flares and does not result into hydrates formation. Gas saturated water moving into channel sand would result into gas hydrates by a very slow diffused mechanism. Such gas hydrates tend to be microbial. On the other hand, if there are faults cutting across such diffusive system, gas hydrates may be thermogenic or thermogenic and biogenic both. It is to be mentioned that the gas hydrate formation is mostly favoured in a region with high sedimentation rates that cause preservation of more organic matter, and generation of less sulfate and more methane. Gas hydrates can redistribute and concentrate in more permeable layers. In the fracture system, gas hydrates are prone to dissolution and re-precipitation, which may fill up the fractures and increase the pressure leading to detours in gas migration. A highly faulted system without a big fault is good for hydrate system. The time & space variability and the geology are the key factors that control the formation of hydrates.

With regard to difference in conventional gas and gas hydrates systems, the source of gas in hydrates may be biogenic or thermogenic or both, but the source of conventional gas is thermogenic. The main constituent of gas hydrates is methane, whereas the constituents for conventional gas are higher molecular weight hydrocarbons. The conventional gas is in-place and mobile but gas hydrates are solid. Traps are required for conventional gas reservoir but are not necessary for the formation of gas hydrates. However, both of them have similar leakage systems. Conventional gas can be recovered directly from the reservoir but gas hydrates cannot be done, as it gets dissociated at STP.

Breakout Session 4: **Methane hydrates related geohazards: slope instability and climate change**, moderated by Dr. Richard Birchwood & Dr. Pawan Dewangan, and attended by 20 participants.

Synopsis: Recent expert opinion at Gordon Research Conference suggests that the Clatharate gun hypothesis is unlikely. As all the methane would dissolve in seawater (Gordon Research Conference), even a big blowout does not escape methane into atmosphere, so carbon emission into atmosphere is also unlikely. The study from the engineering research on Nankai Trough where production test carried out at 12 degree slope and highly sensitive pressure sensors used to monitor the subsidence show that slope instability is not an issue. The potential for slope instability during production depends on areal extent of disturbance. The slope instability does not have a good software and the SUGAR project is pursuing research on this problem. The properties of overlying and underlying sediments adjacent to the methane hydrate reservoir are to be studied carefully, as these sediments respond to stress changes caused by production and have the potential to failure. Laboratory measurement suggests increase in shear strength with gas hydrates but more data is required to ascertain this fact, particularly the data characterizing the change in sediment properties after dissociation. Strength of the sediment after dissociation may return to the strength of the host sediment. However, recent resonant column experiments by Jeff Priest suggest the existence of hysteresis. They increased the gas hydrate saturation in sediments from an initial value and then restored to initial value via dissociation, and found different strengths in the initial and final states.

Few gas hydrates reservoir geomechanics simulators exist. These software should be validated through experiments and by comparing the responses with each other. The constitutive equation used by the software is very important and sensitivity of the software to errors in data

should be known. Considerable uncertainty exists with regard to subsidence during long term production testing. The oil industry has been dealing with this problem during conventional oil production. It may be possible to develop an engineering solution for gas hydrate production based on experience of oil industry.

In KG basin, multiple slope failures are observed in the continental slope region. The depth of submarine slope failure is close to the boundary of gas hydrate stability zone (~ 700-750 m) suggesting the link between the slope failure and gas hydrate dissociation. A systematic investigation of threshold conditions for slope stability is required. The National Institute of Ocean Technology (NIOT), Chennai made an autonomous coring system (ACS) similar to MeBo of SUGAR, which started sinking into the seafloor due to low strength of seafloor sediments. Necessary modification is being planned for future testing of ACS in KG basin. NIOT is exploring a suitable method for extraction of hydrates in KG basin which appears more promising than Mahanadi and Andaman basins. We need to be careful about exaggerating dangers of gas hydrates to the public.

Breakout Session 5: **Methane hydrates in sand and clay reservoirs, and their response to geo-science data**, moderated by Dr. Tetsuya Fujii & Dr. Maheswar Ojha, and attended by 22 participants.

Synopsis: The response of gas hydrate bearing sediments on seismic (Vp, Vs...), electromagnetic, well logs (GR, Resistivity, density, Vp, Vs, porosity...), core data in both the sand and clay dominant reservoirs were discussed. An important question on 'why we don't observe prominent signature on seismic section from the top of hydrate bearing sediments ' in spite of elevation of velocity observed in sonic log, even observed in resistivity log (e.g. KG basin). This may be attributed to the difference in scale and resolution. The well is point data, but the seismic is bulk data. May be velocity alone cannot explain the seismic response, attenuation study is required. Again, a small amount of gas hydrates produces good response that depends on lithology, grain size, compactness etc as has been observed for BSR occurrences in McKenzie delta, Barents Sea etc. It was also discussed that 'seismic blanking' may not be a universal phenomenon for the hydrate bearing sediments. Again, it depends on lithology (clay or sand). The blanking in Blake Ridge has mostly been attributed to the fine clay. The blanking has been observed in MH bearing sediments in Nankai Trough in spite of variation in Vp. Actually, the change in bulk density due to hydrates is very small that does not make significant impedance contrasts within the interval. For the detection and delineation of massive seafloor hydrates observed in Japan Sea, Electromagnetic method may be more useful than seismic method. The attenuation due to gas hydrates show different behaviour in clay and sand bearing sediments.

Breakout Session 6: **Multidisciplinary approach for linking subsurface fluid flow and gas hydrates**, moderated by Dr. Machiko Tamaki & Dr. Aninda Mazumdar, and attended by 20 participants.

Synopsis: The shallow and deep biogenic methane can be characterized using combined studies of $\Delta^{14}C$, $\delta^{13}C$ and δD of hydrocarbon gases. Along the gas migration path different gas compositions may be encountered in deep drill holes. Experimental data are based on ideal condition using specific mineralogy, gas concentrations etc. which is very different from the highly heterogeneous natural setting of hydrate system. Hence integration of experimental hydrate synthesis and realistic field scale observations can greatly help for better modeling. The temperature perturbation owing to hydrate crystallization (exothermic) and thawing (endothermic) at laboratory scale were discussed in relevance to the actual field condition. The methane extraction from hydrate reservoir using depressurization and thermal dissociation were also discussed. Gas hydrate instantaneously degasses on the mineral surface due to chemical potential. It is important to understand this process during sediment burial and hydrate dynamics at the base of gas hydrate stability zone. Besides deep drilling and multichannel seismic data (which are expensive) for the exploration of gas hydrates, an alternative and less expensive method like controlled source electromagnetic survey (?) coupled with sediment pore fluid analyses of piston cores can be used to understand the methane flux. A balanced fluid flow with regard to advective and diffusive methane flux is important for the formation of gas hydrates. Members were of the view that the present knowledge is insufficient to explain climatic perturbation directly to methane release into the atmosphere through hydrate destabilization owing to bottom water temperature increase.

The workshop ended with a valedictory function, which was supposed to be moderated by Prof. Harsh Gupta, Chairman of the Local Organizing/Advisory Committee, but he could not be present due to high fever. As the Convener of the Workshop, **Dr. Kalachand Sain requested the panellists to put forth their observations/comments for further improvement of workshop, and provide steps/strategies to take gas-hydrates R&D way forward and keep the national programs of many countries excited and motivated**. All the panellists appreciated for successful and fruitful organization of the workshop that brought around 100 participants from different parts of the world and India. **It is expected that gas hydrates can be commercially produced by another 10 years time, and Japan may be the first country in the world to claim for this. Remarks of panellists are summarized** below:

- Dr. Saulwood Lin from Taiwan expressed that it was a very successful meeting in terms of sharing new results and disseminating knowledge from wonderful

geophysical data and laboratory experiments. There would have been more discussion on geochemical, microbiological and geological data.

- Dr. Jong-hwa Chun from Korea complimented for well organizing the Workshop. After successful test production of submarine hydrates from Japan offshore, Korean Govt. might decide for conducting test production in 2016, of course it depends on critical analysis of some data.
- Dr. Jiro Nagao from Japan appreciated for nicely completing the workshop, and said that AIST got a chance to be in touch with DGH, ONGC and NGHP specifically in connection with the NGHP Expedition-02. AIST may provide necessary information and guidance to NGHP for conducting any test related to the production of gas from marine gas-hydrates deposits from Indian offshore and any other country in Asia region.
- Prof. Richard Coffin from USA primarily expressed delights for great success of this Fiery Ice workshop and thanked all who delivered very fantastic and excellent results. He appreciated India's efforts to collect and present incredible seismic data, and praised for outstanding interpretation of geophysical and well log data, and stressed upon more results from geochemical, heat flow, controlled source electromagnetic data to build a comprehensive model of gas hydrate system. He was amazed to see lot of people participating to this workshop, and mentioned on the need of a broad scale understanding of methane concentration deep in the system and methane concentration in shallow system. He stressed on the laboratory experiments by adding more than sand or more than clay for comprehensive understanding of the formation, stability and dissociation of gas hydrates. This could be made further realistic with microbial community driven, quantifying age variance and different organic loading.
- Dr. Bjorn Kvamme from Norway said that it was a great session. The gas hydrates system in sediments has never reached the thermodynamic equilibrium. One needs to study by bringing this fact into reservoir simulator at some stage. He also emphasized on the integration of different disciplines working at different scale. There are so many phenomena and multi scale process that are to be known fully. More discussion is required to understand the entire gas hydrates system: why one gets more saturation at some places and low concentration at other places, whether fresh gas is entering the system, how fracture system works. Integration of multidisciplinary approach is a must to understand the dynamics of the fracture and reservoir systems.
- Prof. Werner F. Kuhs from Germany said it was his first and very enjoyable workshop. Certainly integration of different disciplines across the national barriers is needed for better understanding of the dynamic process of gas-hydrates. He focused on multi scale approach from nano scale to Km scale, if needed to atomic scale. He gave a message to young students to learn how to cooperate between different disciplines: listen and learn first what others do, not easy to follow always; understand the key points; and be more deductive. He stressed upon studying the Controlled Source Electro-Magnetics along with the seismics to find answers to some intriguing questions related to gas-hydrates reservoir. He suggested to invite key people to the next workshop with key expertise and open questions.
- Dr. Gareth Crutchley from GNS, New Zealand said that he learned a lot from this workshop. He also mentioned that some issues can be resolved using the controlled source Electro-Magnetic studies along with Seismics. The breakout sessions provided excellent information. He also stressed on the Inter-disciplinary study that brings people from different areas and ideas that cannot be extracted uniquely from one discipline.
- Dr. Tetsuya Fujji from JOGMEC, Japan was very impressed with the analysis and interpretation of seismic data presented at the workshop. Japan is now trying to interpret what happened during the production test of submarine gas-hydrates. They have made different working groups with history matching, geo-mechanics for fluid flow, logging group to fully understand several issues. Their next target is to establish the sand management. In the next production test, Japan looks for gas production increasing tendency. He mentioned that Japan would share the expertise and would like to collaborate with India and other country, if interested.
- Dr. Rajneesh Kumar from NCL, Pune said that it was not an easy task for organizing such a large workshop with so many people due to financial constraints in most of our Govt. organization/ institutes. On Indian perspective, he stressed upon the need of strengthening the work force to expand the gas hydrates research from lab scale to bench scale to pilot scale, and Indian organizations/ Institutes must come together. India has been collaborating with USA and Japan but needs to build her own critical mass of people. He advised to write editorials with a view to educate more people about gas hydrates, and attract young people to pursue advanced research on gas-hydrates.
- Mr. Krishna Vishwanath from DGH, Delhi, Coordinator of Indian NGHP mentioned that several R&D projects related to laboratory, exploratory and

operation aspects have been completed and are being taken up by member organizations. Besides, the joint study between the member organization(s) and the Indian Institute of Technology are also being pursued with a view to understand some critical aspect based on multi-disciplinary approach. The missing gap between the universities and industries can probably be met by this type of workshop. NGHP is also maintaining its relationship with many countries like USA, Japan and Germany for better understanding of gas-hydrates towards the exploration & exploitation. India is almost ready for the NGHP expedition-02 sometimes in 2015.

- Dr. Puspendra Kumar from ONGC, Dehradun, though joined the workshop on the last day, was very impressed by listening to the presentation of six breakout sessions and got the flavour what exactly happened during the last two days. Several issues like whether gas is biogenic or thermogenic, where gas is coming from, how much the resource potential, reason for variation in saturation from place to place, what are the deciding factors for drilling, what kind of technology required for production, methods for identifying massive gas hydrates below seafloor, all discussed during the workshop, are very important to industry for considering gas hydrates as a future major energy resource. He raised a pertinent question whether Japan has postponed the commercial test production by another 10 years till 2028? In response, Dr. Jiro Nagao affirmed that Japan would move to the commercial production, may be after 2028, based on encouraging results on subsequent field test production. Dr. Kumar mentioned that NGHP and ONGC have identified some short-, mid- and long-term research areas, and is in the process of inviting proposal from potential researchers. He also mentioned that NGHP is very cohesive, and encourages different activities for rationalization, and tries to avoid repetition of works by its member organizations/ institutions. He enjoyed the day-long program and complimented the Organizer for making it a very good technical workshop.
- Dr. Kalachand Sain from CSIR-NGRI, on behalf of local organizing/advisory committee, thanked the panellists for their observation and comments, invited speakers for presenting their scientific results/discoveries and all delegates for their active involvement during the workshop. He agreed to Prof. Kuhs's observation that there could have been more discussion covering different disciplines/ fields of gas-hydrates. He mentioned that about 150 letters of invitation were sent to topmost scientists, technologists, academician, industry people working in the field of gas hydrates at different countries. However, it was very difficult to get people from different disciplines on a single date at a single platform, as someone wrote that he had teaching load, someone was in the field cruise, someone attended just concluded seminar/ workshop, someone had no fund to attend, someone had other commitment... etc. Dr. Sain brought to the notice of all concerned that to make a workshop very successful, deliberations are required on recent results/discoveries on gas-hydrates not only from geo-science data but also from technological advancement, laboratory study, production tests, and many other issues by those who proved themselves as world-leaders in different countries. There should be some seed fund available. He was fortunate to organize this Workshop at HICC, Hyderabad due to financial support obtained timely from the University of Bergen, Hawaii University, US Dept. of Energy, and many Indian Organizations/Institutes like the Ministry of Earth Sciences, Council of Scientific & Industrial Research, Department of Science & Technology, National Geophysical Research Institute, National Institute of Oceanography, National Center for Antarctic & Ocean Research, National Institute of Ocean Technology, Oil India limited, Gas Authority of India Limited. The success of this workshop has been possible because of great initiatives and full cooperation provided by Dr. Richard Coffin, Prof. Bjorn Kvamme, Prof. Stephen M. Masutani, Prof. Tsutomu Uchida, Prof. Hideo Narita, Prof. Harsh Gupta since its beginning. He also mentioned that the next workshop is very important in terms of celebrating the decade of IMHRD Workshop.
- Prof. Kvamme said that the point of having seed fund as mentioned by Dr. Sain is noted down and would be discussed with other members of International Steering Committee. He also said that it was really difficult for many key people to attend the 9th workshop due to various reasons. Prof. Kvamme added that Taiwan and Singapore already expressed their desire to host the next workshop. However, the decision would be made at a later date, and he urged for one page proposal by other country representatives, if interested. Dr. Richard Coffin asked comments from the delegates for further improvement of workshop and invited all National representatives to email him the proposal for the 10th IMHRD Workshop. He mentioned that Hawaii, Alaska, Singapore and Taiwan have expressed their interest. Since Taiwan was ready with proposal, Dr. Saulwood Lin from Taiwan was asked to present the proposal, and he made a beautiful presentation.
- Everybody in the audience appreciated for successfully and fruitfully finishing the workshop.

A photo of Cultural Program in the evening of November 10, 2014

A group photo at the end of the Valedictory Function on November 12, 2014

A poster session during the IMHRD Workshop

Group photo of participants at the Golkonda Fort - a historical place of Hyderabad in the eveninhg of November 12, 2014.

Group Photo before leaving for the Geologic Field Excursion at Nagarjuna Sagar, near Hyderabad on November 9, 2014.

The field excursion, led by Dr. TRK Chetty, EVSSK Babu and T. Vijay Kumar of CSIR-NGRI, provided a (i) glimpse of the Archaean greenstone belts, Precambrian granites and gneisses, and Proterozoic sediments in Eastern Dharwar Craton, (ii) sight of the Nagarjuna Sagar reservoir - a major multipurpose irrigation project, and (iii) glance of one of the largest (masonry) irrigation dams in Asia called the Nagarjuna Sagar.