THE GEOLOGICAL SOCIETY
THE PETROLEUM EXPLORATION SOCIETY OF GREAT BRITAIN

SUBMISSION TO ROYAL SOCIETY / ROYAL ACADEMY OF ENGINEERING INQUIRY INTO SHALE GAS

The specific questions posed by the Royal Society/Royal Academy of Engineering were as follows:

- Comments were invited on the main perceived risks of extraction (methane in groundwater, induced seismicity, water use and contamination from fracking fluids, but not impact of use of the gas, i.e. carbon emissions).
- Is the UK skills base appropriate? What needs improving?
- What are the R&D priorities, and how should Research Councils be involved? (Gaps in the knowledge base, addressing areas of risk and uncertainty.) Should they bring people together to brainstorm the science/engineering issues? Who?
- What further work needs to be done to provide the scientific basis on which government can decide whether it should proceed? (For example, should BGS look further at resource assessment, baseline surveys, etc.)
- What are the uncertainties in risk assessment and management?
- Does the regulator have the requisite scientific competence and capacity?
- To what extent is non-industry funded research needed if there is to be scientific and public confidence in the process?
- Are there lessons from elsewhere (e.g. radwaste) on the relationship between geoscience and public engagement?

1. This submission has been produced jointly by the Geological Society of London and the Petroleum Exploration Society of Great Britain:

   i. The Geological Society of London (GSL) is the national learned and professional body for geoscience, with over 10,000 Fellows (members) worldwide. The Fellowship encompasses those working in industry, academia and government, with a wide range of perspectives and views on policy-relevant geoscience, and the Society is a leading communicator of this science to government bodies and other non-technical audiences.

   ii. The Petroleum Exploration Society of Great Britain (PESGB) represents the national community of Earth scientists working in the oil and gas industry, with over 5,000 members worldwide. The objective of the Society is to promote, for the public benefit, education in the scientific and technical aspects of petroleum exploration. To achieve this objective the PESGB makes regular charitable disbursements, holds monthly lecture meetings in London and Aberdeen and both organises and sponsors other conferences, seminars, workshops, field trips and publications.

2. This submission has been developed and signed off at relatively short notice. Given the limited resources of our two organisations, it has not been possible to provide full responses to all the questions identified in correspondence. We have also been careful to focus our remarks on those areas in which our communities have relevant expertise and experience. We would be pleased to discuss with the Royal Society and the Royal Academy of Engineering how a more detailed assessment of some of the issues raised might be achieved.

3. We note that the environmental impacts being considered by the present inquiry are restricted to those connected with the exploration for, and production of, shale gas. The impacts to be considered do not include the effects of subsequent use of gas that is produced. As a means of focusing on operations, this restriction in scope of the inquiry is understandable. As a means of addressing public concerns about shale gas, such a restriction is undesirable. To give environmental clearance to producing shale gas without addressing in some fashion the wider environmental impacts of its use would be unwise. We commend the approach of the Chair of the House of Commons Energy and Climate Change Committee, Tim Yeo MP, who in our view correctly stated that shale gas could be safely produced, but added that the emergence of shale gas as a major fossil fuel increased the 'urgency of bringing carbon capture and storage technology to the market and making it work for gas as well as coal.' (Select Committee Announcement 45a, 23 May 2011.)

Identification, assessment and management of risks and uncertainties

4. To establish and maintain public confidence in any shale gas exploration or production programme, it is important that all significant perceived risks and uncertainties are given serious consideration, whether or not they are considered to be material by technically expert communities. We agree with the approach which we understand the working group is taking – first, to ask whether such activity *could* be carried out safely; and second, to ask whether it *would* be done safely. The first question is essentially one of risk identification and assessment, and the second of risk management (in particular, of ensuring appropriate and

effective regulation). We remain confident that, given sufficient care and attention, it is possible to locate and extract shale gas safely. Below we consider some of the potential risks and uncertainties which have been posited regarding shale gas exploration and production (E&P) with respect to safety and local environmental impacts.

5. ***Water sourcing and subsequent disposal.*** Hydraulic fracturing ('fracking') requires a great deal of water to be injected, much of which then returns safely to the surface as part of the subsequent production operations, salinated and containing other chemicals added to the fracking fluids. These chemicals are familiar to the hydrocarbons industry from conventional drilling, and we see no reason to believe that, given appropriate regulation, water cannot be sourced and disposed of without endangering human health or the local environment. But the fact that companies generally do not publicly disclose the composition of their fracking fluids makes it difficult to demonstrate that they are being dealt with safely, and are subject to appropriate and effective regulation. Those implementing such regulation would need to have (or otherwise have access to) the knowledge and skills to assess the validity of operators' statements of fracking fluid compositions.

6. ***Groundwater contamination from hydraulic fracturing.*** Some have suggested that groundwater (and hence domestic water supplies) near to hydraulic fracturing operations may become contaminated, either with the chemicals used for fracking, or with methane and other hydrocarbons and naturally occurring compounds released by fracking. This is unlikely in operations where the fracturing takes place at depths of many hundreds of meters below the groundwater aquifer and no migration routes exist. (Typically, there is a considerable thickness of impermeable or low permeability shales between the shale gas horizon and the near-surface aquifer.) A more likely source of methane in groundwater is that which occurs naturally at shallower depths. This shallow methane can in principle be distinguished from the methane occurring at depth in shales: in practice this will require research both before and during operations. Another possible cause for both methane and fracking fluids leaking and migrating into groundwater supplies is the fracture stimulation process intersecting with open or unstable natural fractures and faults in the subsurface that extend upwards from the deeper prospective layers towards the surface where groundwater supplies might exist. Another possible cause of such fluid migration is poor well integrity. There are several aspects to well integrity, including well design, integrity of the cement bond between the casing and the well bore, and composition of the casing in the context of its

ability to resist corrosion. If all these aspects are appropriately and effectively assessed, understood and regulated, it is possible to construct and operate wells without endangering human health or the local environment. A further source of potential contamination of near-surface groundwater is leakage from surface fracking fluid storage and processing facilities.

7. ***Release of radioactive material.*** The risk of mobilising natural uranium from source rocks has been raised in the research literature. We are not aware of any evidence of harm.

8. ***Induced seismicity.*** Any risk that fracturing might cause earthquakes capable of causing noticeable surface movement in the UK can be reduced to negligible levels by avoiding injection into or near to faulted zones, and by careful well planning to avoid such zones during any drilling operations. Micro-seismicity will result whenever large volumes of fluid are injected into rock – for instance, in carbon capture and storage (CCS) or geothermal energy generation. Many other drilling operations also induce micro-seismicity. This is well known and understood in the hydrocarbons industry, and any associated risks are already effectively managed in existing E&P contexts. This is therefore not an unfamiliar risk to subsurface scientists and engineers. Moreover, operating companies routinely draw on background knowledge derived from other applications in order to identify relevant uncertainties and then to minimise and manage such risks, especially in planning well locations to avoid significant faulted or unstable zones.

9. ***Carbon emissions.*** As noted in our opening comments, we recognise that the inquiry is not intended to consider the global environmental impact of extracting and using shale gas, including carbon emissions. However, it is important to recognise that there is not a clear boundary between these and local environmental impacts, for instance when addressing concerns about possible leakage of methane to the atmosphere due to poor well integrity.

10. ***Social and visual impact.*** This is a possible public concern regarding onshore hydrocarbons E&P generally. But the UK hydrocarbons industry has demonstrated that it can successfully exploit resources while meeting the highest environmental and social standards. Wytch Farm, the largest onshore oil field in Western Europe, was discovered by British Gas in the 1970s and operated by BP since 1984 until the recent sale of its interest to Perenco. It is located in one of the world's most famous and sensitive regions of outstanding beauty and natural interest (not least because of its geology and geological heritage), which includes the Jurassic Coast World Heritage Site, designated wetlands of

international importance, and national nature reserves. World standards in environmental protection and community engagement have been set at Wytch Farm, using horizontal drilling at distances of more than 10km, keeping the size of well sites to a minimum, and adding considerably to the capital cost of the gathering station by restricting height of facilities to below the tree line, in order to minimise environmental and visual impacts. It is worth noting that in the case of Wytch Farm, production facilities could be hidden within an existing plantation of mature trees, an advantage that would not apply everywhere in the areas of potential shale gas operations. Members of the public looking out over the area are likely to be unaware of the existence or scale of the Wytch Farm operations in question. The key is to set regulations which reflect the required environmental and social standards, and also to minimize the footprint and disturbance caused by any operational activities. This is well within the scope of industry, given a suitably informed and expert regulatory environment to ensure that appropriate standards are defined and adhered to.

What R&D is required?

11. R&D is required not just with regard to real or perceived risks and uncertainties about impacts, but also to understand better the extent of shale gas resources in the UK, and to improve the efficiency of their identification, characterisation and extraction. These factors are not only commercially important, but are germane in considering how much time and expense can be justified in assessing risks and ensuring appropriate and effective regulation. We note that a number of UK and other European institutions are in the early stages of significant shale gas research programmes.

12. More is known about the geology of the UK than that of almost anywhere else in the world – but while we know that there is potential for shale gas, and we have a great deal of background data, work to determine the size of the resource, and whether it is economically viable to extract, remains in its early stages, particularly because past exploration has not been carried out with the objective of identifying shale gas resources. Work is underway to identify and characterise potential shale gas resources, as well as to improve our understanding of the relevant geology, which in turn promises better characterisation, and hence improved resource estimates and productivity (for instance by helping identify 'sweet spots' in gas plays).

13. Shale gas plays vary enormously in their properties and characteristics. In particular, the favourable geology characterising most of the major US plays –

such as thick, high TOC (total organic content) oil-prone source rocks with low clay contents, deposited in large, relatively unstructured basins – are not generally found elsewhere. European plays tend to be smaller and more complex. In many places, there is a high level of heterogeneity within plays, on a scale of metres to hundreds of metres horizontally, and down to centimetres vertically. These challenges are not intractable; they drive research and data gathering, but could act as a limiting factor to commercial development.

14. Companies incur significant commercial risk whenever they undertake drilling, both for exploration and for production. They depend on high-quality science, done by themselves and by others, and on the development of new technologies to minimise and manage this risk. The same approach should be taken to environmental risk and safety – indeed, there are likely to be synergies between the research and development required to address both sets of risk.

15. Production at commercial scale will require technology development. In particular, it will be necessary to perform more extensive hydraulic fractures than at the testing and exploration stage, while ensuring acceptable access to water and care of its disposal.

16. ***Induced seismicity.*** To discriminate seismic events induced by human activity from natural ones, and to characterise them, it will be necessary to establish the background/baseline conditions prior to drilling, using the database of the British Geological Survey and other records. Micro-seismic monitoring networks could then be used to monitor the level of seismic activity during and after the fracking process. This would be a significant undertaking, and would incur cost and delays to any drilling operations. A benefit would be to help build public confidence as well as to mitigate operational and production risks.

17. ***Groundwater contamination.*** Again, in order to identify any effect of operations on groundwater, it would be necessary to undertake a baseline survey before drilling operations begin. This might measure methane levels in the aquifer, but also other organic compounds such as benzine. A full geochemical analysis would be required to identify all possible contaminants, whether from fracking fluids or released from the rock (at depth or around the well). Expert advice would be required to develop a list of chemicals and minerals that should be analysed, depending on the scope and purpose of the baseline monitoring. As noted above, further research is required to improve differentiation of thermogenic methane occurring at depth in shales from shallow thermogenic or biogenic methane (either naturally occurring, or artificially stored underground).

In addition detailed structural geology and geomechanical studies would be required to identify potentially unstable zones and faults in the subsurface as well as to understand regional and local subsurface stress regimes. We have the capability to do this work in UK universities and research institutions where there is already a recognised and established track record of world class research to address these issues. A focussed and collaborative research effort will be needed to address all of these uncertainties and risks enabling an informed and well-regulated decision on safe exploration, development and production of shale gas resources in any prospective area, as well as to assure public confidence.

18. Geoscientists working in areas such as radioactive waste management are used to working with risk and uncertainty in interdisciplinary settings, in which a high value is placed on public and stakeholder engagement (PSE) and confidence. The other specialist disciplines involved include not just natural sciences and engineering, but also social sciences (both regarding substantive aspects of implementation, and in PSE and process design). There is growing recognition that balancing natural science, engineering, social science and public and stakeholder inputs is not a 'zero-sum game' in which more and better geoscience in the process, for instance, can only be accommodated at the expense of social science or PSE inputs. Rather, the use of the right geoscience at the right points in the process is a vital part of the 'tool kit' for engendering public confidence, and for ensuring that public and stakeholder inputs are well-directed and effective. There may be lessons to be learned with regard to building public confidence in shale gas E&P – though it would be unwise to draw any parallels between the technicalities of the two cases, other than that both rely on understanding the behaviour of the subsurface. Finally, to reinforce the point we made in our opening remarks, whatever the restrictions in scope of a particular inquiry (operations, in this case), it is sound practice to set any conclusions about environmental impact in its broader context (such as environmental consequences of the use of the product).

Skills requirements

19. Many of the skills required for shale gas E&P are the same as for other hydrocarbon resources, and are plentiful in the UK oil and gas industry. This includes not just operating companies, but also the geoscientific service industry, which supplies geological consultancy and expertise to hydrocarbons companies with regard both to exploration and production. Such expertise and services derive from academia and the British Geological Survey (BGS), as well as from the commercial sector. Although there is little history of unconventional gas

exploration and production in the UK, there is no reason to think that the requisite service industry is a limiting factor. UK service industry geologists are among the best in the world. The geological understanding required for conventional and unconventional gas E&P is similar, though there are particular technologies (horizontal drilling and hydraulic fracturing) which are less developed in Europe in comparison to the US, unsurprisingly given the immaturity of the unconventional gas industry in Europe. But these techniques are familiar to the industry. The service industry in Europe is sufficient for the current testing phase of shale gas exploration, and can be expected to develop as long as there is sufficient supply of suitably skilled and trained people from education. The successful 'conventional' hydrocarbon extraction operation at Wytch Farm, which set new records for horizontal directional drilling distances, both demonstrates the fitness for purpose of the UK service industry for horizontal drilling (and for onshore development), and constitutes a site for learning from best practice.

20. Whilst there are some differences between the geology and the nature of shale gas resources in the UK (and elsewhere in Europe) and those in the US, there is significant scope and need for international learning and knowledge transfer. Research and the development of new technologies and business models have been stimulated by the development of the US shale gas industry. Notably, many global, European, Indian and Chinese companies have acquired small percentages of US shale gas plays, to build their knowledge, technology base and human capital. In applying this expertise to a European context, it is vital not just to transfer technical skills, but also to adapt to a different social, regulatory, geological and commercial environment. One example is the need to minimise the footprint of UK operations, because of greater constraints on land use.

21. Some of the skills which will be required by the regulators to set appropriate regulations and to implement them effectively are noted or implied above. We are not sufficiently familiar with the operations and skills base of the regulators to comment on whether they have the requisite scientific expertise and capacity. They are likely to rely upon consultancy from the commercial sector, universities and BGS, both for data such as that from baseline monitoring and also to provide scientific advice to enable and ensure safe, reliable and environmentally sensitive operations. They may also commission other expert advice, consistent with their role and responsibilities.

22. The Geological Society, working with other organisations including the PESGB and the BGS, has recently established a Geoscience Skills Forum. Its purpose is to gather evidence regarding national geoscience skills needs, focusing initially on a number of sectors including hydrocarbons, to identify current and potential

future skills gaps, and to stimulate work to address these needs across industry, academia and government. Our initial evidence gathering is not complete, but a widespread concern is that taught applied Masters programmes, which are highly valued (and sometimes a prerequisite for entry to the profession) in many sectors of geoscience, may be at serious risk as a result of the withdrawal of Research Council studentships, in combination with the greatly increased levels of debt with which students will graduate from Bachelor degrees in future. This is a potentially significant threat to the local (UK based) supply (capability and capacity) of trained personnel to the hydrocarbons industry.

Aspects of implementation

23. Research Councils have a vital role to play in identifying research challenges, particularly more fundamental science, and stimulating work to address these challenges by setting the strategic direction. The principal Research Council for research relating to shale gas should be NERC; EPSRC could usefully play a supporting role. To the best of our knowledge, there is no NERC or cross-council programme addressing shale gas or other aspects of unconventional hydrocarbon resources (excepting CCS). With respect to CCS, there may prove to be competing demands for commercial and scientific use of the subsurface, and for personnel with relevant expertise; mitigating this risk and ensuring that appropriate contingencies are in place requires sound channels of communication between Research Councils, and between other public bodies. While applications for funding for research on aspects of shale gas could undoubtedly be justified in the context of existing science themes and projects, NERC could arguably provide stronger leadership to the research community in this area. (These comments refer to NERC in its role as a Research Council. Of course BGS, which is a NERC research centre, plays an important role in research and communications regarding shale gas. However, it does not have the capability and expertise to cover all aspects of shale gas research and technology requirements.) If the inquiry identifies research challenges which it regards as important for building scientific and public confidence in shale gas E&P, we would support proposals for NERC to take the lead in addressing these, and would be prepared to play our part in brokering dialogue between the Research Councils and the academic geoscience community.

24. The extent to which non-industry funded research takes place is probably not a significant factor in building confidence in shale gas E&P in the professional geoscience community (although as noted above, Research Councils have a

vital role to play in funding more fundamental research). First, confidence among this group is high in any case. Second, the petroleum geoscience community spans academia, industry and government (particularly BGS), and is noted for its track record of close integration between theory and practice. The Geological Society's Petroleum Group and the PESGB routinely bring together the best practitioners from across these sectors, to exchange views, knowledge and research findings through their scientific meetings and publications. There is a high level of trust (and of mobility of personnel) across the sectors, which frequently collaborate on research projects.

25. The question of whether non-industry funded research is important in engendering public confidence is less straightforward. Most of the work relating to implementation and application, rather than to the underlying geoscience, is done in industry, which is also where much of the relevant technological expertise resides – while critical skills, notably in underpinning and fundamental science, largely reside in our universities and other research institutions. Many research projects relating to shale gas reflect and will demand collaboration between academia and industry, as is the case in hydrocarbons research more generally (see above). So the knowledge and research required to underpin the prospective shale gas industry in the UK, and to address public concerns (whether about the general environmental impact of using fossil fuels, or specifically about shale gas operations) cannot be sourced entirely from outside industry. In this context, the public needs independent rational assessment of the scientific and technical assertions made both by those opposed to shale gas operations, and in the public statements of oil and gas companies and those who promote their interests. The Geological Society and the Petroleum Exploration Society of Great Britain already play a leading role in communicating to policy-makers and the public the relevant basic and applied science, which are so powerfully brought together through their internally diverse membership, to ensure that debate and decision-making about whether shale gas operations should proceed (and under what regulatory regime) are well-informed. We intend to increase our combined efforts in this area.

26. Experience in the USA suggests that the hydrocarbons industry has failed to convince many of the safety of unconventional gas exploitation. Decision-makers have been hindered by confusion in the public debate between the safety of operations conducted by the oil companies on the one hand and, on the other, the effects of additional carbon dioxide released to the atmosphere as a result of the use of these additional fossil fuel resources by the oil companies' customers. Government, regulators, forward-looking oil and gas companies, and responsible

environmentalists, will all appreciate the support of learned and professional bodies in ensuring that the debate on shale gas in the UK draws appropriate distinctions between the safety of operations and the safe use of products.

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