

TECHNICAL REVIEWERS' RATING SUMMARY

G-013-B

Surface Microseismic Study of a Bakken Fracture Stimulation

Submitted by Marathon Oil Company

Principal Investigators: Ken Dunek and Chuck Meeder

Request for \$155,000; Total Project Costs \$310,000

Rating Category	Weighting Factor	Technical Reviewer			Average Weighted Score
		<u>13B-3</u>	<u>13B-4</u>	<u>13B-9</u>	
Objective	9	4	4	4	36.0
Availability	9	3	4	2	27.0
Methodology	7	3	5	3	25.7
Contribution	7	4	4	3	25.7
Awareness	5	2	5	3	16.7
Background	5	4	5	3	20.0
Project Management	2	3	5	3	7.3
Equipment Purchase	2	5	5	5	10.0
Facilities	2	3	5	5	8.7
Budget	2	4	5	5	9.3
Average Weighted Score		172	225	162	186.3
Maximum Weighted Score					250

OVERALL RECOMMENDATION

FUND	X
FUNDING TO BE CONSIDERED	X
DO NOT FUND	

G-013-B
“Surface Microseismic Study of a Bakken Fracture Stimulation”
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1. The objectives or goals of the proposed project with respect to clarity and consistency with North Dakota Industrial Commission/Oil and Gas Research Council goals are: 1 – very unclear; 2 – unclear; 3 – clear; 4 – very clear; or 5 – exceptionally clear.

Reviewer 013B-03 (Rating: 4)

If the PSET technology of MicroSeismic, Inc. is proven viable in the Williston Basin of North Dakota by this experiment, it could provide oil and gas producers another option for determining the induced fracture azimuth and lateral coverage during a hydraulic fracturing treatment. This surface micro-seismic monitoring technology is particularly applicable to wildcat areas where down-hole tiltmeters and down-hole micro-seismic methods are not possible due to well spacing limitations.

Reviewer 013B-04 (Rating: 4)

The goals of this proposal are directly aligned with 4 of the 5 OGRC Goals and Purposes.

Reviewer 013B-09 (Rating: 4)

The project objective is to gain understanding of stress regime and fracture network within the Bakken Formation. Given that Bakken play is one of the most important producing horizons in North Dakota these days the objective certainly contributes to the NDIC/Oil and Gas Research Council Goals.

2. With the approach suggested and time and budget available, the objectives are: 1 – not achievable; 2 – possibly achievable; 3 – likely achievable; 4 – most likely achievable; or 5 – certainly achievable.

Reviewer 013B-03 (Rating: 3)

The mobilization and demobilization costs seem quite high, even considering the remoteness of North Dakota from other areas using this technology. The funding requested by the investigators amounts to covering slightly more than those costs as given in the cost breakdown. Hopefully, some way can be found to reduce that portion of the total cost so the OGRC funds can be more efficiently utilized to generate research quality data.

Marathon Oil Company's response

Mobilization/demobilization costs are indeed high because the seismic crews are not presently available in the area. If this work is proven beneficial, more surface monitoring projects are expected by a number of operators in North Dakota so the amount of work will justify maintaining a crew in North Dakota thereby reducing mob/demob costs to a lower level. In addition, frac jobs can be scheduled to coordinate multiple projects and activities of several operators to share these costs among wells.

Reviewer 013B-04 (Rating: 4)

The only concern is the ability to detect seismic signals through the massive salt sections typical in the Williston Basin. There is no way to know for certain until a project like this one is completed.

Reviewer 013B-09 (Rating: 2)

The proposed approach tends to utilize data from surface microseismic monitoring to characterize Bakken fracture network. However, Bakken has a significant depth and level of noise on the surface is not known (at least it is not addressed in the proposal). Some researchers believe that for deeper work companies are actually representing surface noise as microseisms. I would recommend requesting the proposer that more justification of the efficiency of the technique in the given settings was provided.

Marathon Oil Company's Response:

The SEG publication by Lakings, et al included in the proposal is one example that illustrates a good correlation between fracture-related microseismic events detected and located by the surface seismic method and the downhole method. The depth in this case was 7800 ft.

3. The quality of the methodology displayed in the proposal is: 1 – well below average; 2 – below average; 3 – average; 4 – above average; or 5 – well above average.

Reviewer 013B-03 (Rating: 3)

There appears to be minimal published information supporting the successful use of PSET technology in conjunction with hydraulic fracture monitoring at the typical depth of the Bakken formation in the Williston Basin of North Dakota. It is unclear whether the lack of published data is simply due to a current lack of sufficient application at this depth or a deficiency in performance at this depth. PSET will likely provide comparable results to those obtained by tiltmeters, if successful.

Reviewer 013B-04 (Rating: 5)

The proposed methods represent a logical and rational application of the best available current technology.

Reviewer 013B-09 (Rating: 3)

The proposed methodology is one of those attracting much attention from the scientific society. However, it is unclear how efficient the methodology would be in the given project. It can be suggested that using borehole microseismic over the surface installation was used. It is indicated in the proposal that proposer has already conducted studies (e.g., tiltmeter study) contributing to the objective of the current proposal. A discussion on the progress can be useful as well.

Marathon Oil Company's Response:

An objective is to find the best, most effective approach for mapping the effective area of the frac job. The borehole method is excessively expensive due to the cost of drilling a monitor(s) well, or alternatively impacting the effectiveness of the producing well program by drilling wells at only about 1500 ft spacing. A single monitor well can only detect events out about 2000 – 3000 ft away from the monitor well which in practice images a much smaller part of the well that is having the fracture stimulation placed.

The tiltmeter study in which the Research Council has funded will take place in late June on the Marathon Klatt well.

4. The scientific and/or technical contribution of the proposed work to specifically address North Dakota Industrial Commission/Oil and Gas Research Council goals will likely be: 1 – extremely small; 2 – small; 3 – significant; 4 – very significant; or 5 – extremely significant.

Reviewer 013B-03 (Rating: 4)

This PSET experiment could provide very useful information for oil and gas producers operating in the Williston Basin of North Dakota concerning the azimuth and lateral coverage of induced hydraulic fractures. If successful in acquiring quality data, the PSET information would be helpful, even if the technology does not prove an economical or practical option for all operators and producing areas of North Dakota. As in the case of surface tiltmeters, quality information about the vertical dimensions and propagation of the induced hydraulic fracture will likely not be produced.

Reviewer 013B-04 (Rating: 4)

The scientific and technical contribution of this work will add a great deal to Bakken drilling and completion practices in the state. The value is slightly diminished by the 1 year confidentiality period requested, but the huge capital contribution of the investigator fully justifies the request

Reviewer 013B-09 (Rating: 3)

If the methodology proves to be effective for reaching the proposal goal it will provide an opportunity for others to design their wells and produce more efficiently. In case of success the contribution to the NDIC goals will be significant.

5. The principal investigator's awareness of current research activity and published literature as evidenced by literature referenced and its interpretation and by the reference to unpublished research related to the proposal is: 1 – very limited; 2 – limited; 3 – adequate; 4 – better than average; or 5 – exceptional.

Reviewer 013B-03 (Rating: 2)

The investigators have provided a technical reference paper describing a case history application of the PSET technology. It appears that little additional published technical data exists at this time outside of vendor product documentation. The text of the proposal and the indicated industry background of the investigators would indicate a satisfactory understanding of the PSET technology is likely.

Marathon Oil Company's Response:

The technology has also been used for other applications like monitoring microseisms generated along faults due to changes of effective pore pressure during production in the North Sea. More data is needed to further test and evaluate the technology and its applications and limitations.

Reviewer 013B-04 (Rating: 5)

The investigator and contractor are the authors of many of the current publications in this field.

Reviewer 013B-09 (Rating: 3)

The PI is certainly aware about the current status of the research in the direction the proposed project is going to follow. However, if the shortcomings of the proposed methodology were discussed in the proposal it would provide more evidence that the research team is well prepared for the project, particularly to face its challenges

6. The background of the investigator(s) as related to the proposed work is: 1 – very limited; 2 – limited; 3 – adequate; 4 – better than average; or 5 – exceptional.

Reviewer 013B-03 (Rating: 4)

Both investigators, based on the provided credentials and the proposal text, appear to possess adequate knowledge of the hydraulic fracturing and PSET seismic technologies involved and the need for the type of induced fracture azimuth and lateral coverage data to be acquired.

Reviewer 013B-04 (Rating: 5)

The investigator's credentials and experience are exceptionally well suited to the proposed work.

Reviewer 013B-09 (Rating: 3)

Investigators have a lot of experience in the application of the geophysical techniques. However, the proposed methodology is a little bit different from what the investigators have done in the past.

7. The project management plan, including a well-defined milestone chart, schedule, financial plan, and plan for communications among the investigators and subcontractors, if any, is: 1 – very inadequate; 2 – inadequate; 3 – adequate; 4 – very good; or 5 – exceptionally good.

Reviewer 013B-03 (Rating: 3)

The implementation plan will require very close coordination with all the services involved to reduce expenses related to waiting time. Current demand for all oilfield services in the Williston Basin is high and delays in a schedule can result in other necessary services becoming unavailable. Complex oilfield operations within the Williston Basin of North Dakota are dissimilar to those within other major oil and gas operating areas where multiple service locations and vendors exist at a reasonable distance to provide support and backup within a useful time frame.

Marathon Oil Company's Response:

The coordination of activities is recognized as a significant issue for this project and best efforts are planned to minimize costs and maximize efficiencies.

Reviewer 013B-04 (Rating: 5)

The time table, management plan, and communication plan are all clearly defined and well financed.

Reviewer 013B-09 (Rating: 3)

The milestones, schedule and financial plan are well defined. However, the risks are not discussed and no pathways to mitigate the risks are proposed.

8. The proposed purchase of equipment is: 1 – extremely poorly justified; 2 – poorly justified; 3 – justified; 4 – well justified; or 5 – extremely well justified. (Circle 5 if no equipment is to be purchased.)

Reviewer 013B-03 (Rating: 5)

There is no indication any equipment will be purchased specifically for this project.

Reviewer 013B-04 (Rating: 5)

No equipment purchases are planned.

Reviewer 013B-09 (Rating: 5)

No equipment will be purchased.

9. The facilities and equipment available and to be purchased for the proposed research are: 1 – very inadequate; 2 – inadequate; 3 – adequate; 4 – notably good; or 5 – exceptionally good.

Reviewer 013B-03 (Rating: 3)

The PSET technology has been shown to work in other areas to provide induced hydraulic fracture azimuth and lateral coverage data as indicated in the proposal. The ability of PSET to satisfactorily monitor the propagation of a hydraulic fracture at the typical depth of the Bakken formation through a typical Williston Basin stratigraphic column has not been clearly demonstrated. However, since this is an experiment, that should not preclude an attempt to prove the viability of the PSET technology in that same operational environment. The proposal includes detailed information concerning the setup, location, and operation of the PSET monitoring equipment in this experiment.

Reviewer 013B-04 (Rating: 5)

The investigators are in direct control of most facilities and equipment. Only 1 primary contractor is required and they have already scheduled the work to the extent possible.

Reviewer 013B-09 (Rating: 5)

It is expected that modern technologies will be used for the project completion.

10. The proposed budget “value”¹ relative to the outlined work and the financial commitment from other sources is of: 1 – very low value; 2 – low value; 3 – average value; 4 – high value; or 5 – very high value. (See below)

Reviewer 013B-03 (Rating: 4)

The value of the data resulting from this experiment is very high in regard to furthering the efficient completion of Bakken horizontal wells and maximizing productivity. If PSET technology proves effective, it will provide an alternative to surface tiltmeters for monitoring the propagation of an induced hydraulic fracture. Furthermore, a viable alternative method of obtaining that same data will likely result in the more competitive pricing of either technology to the benefit of oil and gas operators in North Dakota. Competitive pricing should result in more applications of either technology by other operators in other areas of the Williston Basin in North Dakota. The investigators have indicated Marathon Oil Company is committed to providing 50% of the direct cost of the PSET implementation if the proposal is approved.

Reviewer 013B-04 (Rating: 5)

The principal investigator is investing millions of dollars in the well bore and fracture treatment to make this data acquisition proposal possible. The value of this work is perhaps millions of barrels of additional oil recovery. The OGRC investment is leverage many fold.

Reviewer 013B-09 (Rating: 5)

Marathon will incur more than 50% of the costs associated with the project completion.

Section C. Overall Comments and Recommendations:

Please comment in a general way about the merits and flaws of the proposed project and make a recommendation whether or not to fund.

Reviewer 013B-03 (Funding May Be Considered)

The proposal to compare the two competing technologies is worthy of consideration. However, I do have some concerns the PSET technology may be approaching or exceeding technical limits at the depth of the Bakken formation and may not succeed for that reason. All published data I have been able to acquire indicates the maximum documented depths for successful application are around 6,000 ft. As is often the case, however, not all case histories for oil and gas operators are made available for publishing, so lack of proof of performance is not proof of a lack of performance. Ultimately, proof of application will be one of the desired results of this experiment

If micro-seismic technology has difficulty detecting and locating the source of a micro-seismic event over distances in excess of 1,500 ft horizontally, within a single continuous lithology unit, it seems intuitive that acquiring similar data vertically through >10,000 ft of layered, multiple lithologies, including at least three salt beds, would be exceptionally difficult. I also suspect detection problems will exist in areas with substantial deposits of unconsolidated sand, gravel, and boulder laden glacial till overlying the bedrock.

It is unfortunate neither of the competing technologies, surface tiltmeters or surface micro-seismic is likely to produce reliable vertical fracture geometry, as I believe this is a very important and very misunderstood part of hydraulic fracture design in the Williston Basin portion of North Dakota. Downhole micro-seismic and tiltmeter methods that accurately provide this data need to be supported at some time, regardless of the cost and operational difficulties. Operators who currently are pursuing the Bakken formation within established fields, with available monitoring wellbores, need to be encouraged to participate in acquiring the data.

It is unclear from this PSET application whether the previously approved grant to Marathon Oil Company for using surface tiltmeters will be applied to this same well or to another well. Obviously, for comparison purposes, having both technologies on the same well would be the ideal controlled experiment. This arrangement would reduce the chance subsurface conditions at the location would bias one experiment over the other. However, it is also important to realize this arrangement doesn't totally remove location bias, as surface conditions may favor one technology over the other. Ideally, this experiment utilizing multiple, competing technologies would be repeated in other areas to quantify the impact of surface conditions.

Marathon Oil Company's Response:

The distance limitations of the downhole monitoring method is so restrictive because the method requires having good enough signal to noise ratio on individual data channels to accurately pick arrival times of compressional and shear waves. While surface conditions are clearly noisier environments than downhole, the surface monitoring methods are multichannel and use statistical correlation methods to identify microseismic events, The power of the seismic stack helps to overcome some of the noise problems at the rate of square root of the number of traces. Also, the pattern of seismic lines radiating outward from the well surface location provides the noise reduction of geophone arrays to reduce the coherent noise generated by the activity on the pad.

It is not presently known exactly what the impact of the local environment (surface, near surface, and subsurface) will have on the effectiveness of PSET, but only a field test can directly address these questions.

The intent is to compare PSET with tiltmeter results, and there has been considerable discussion of the relative benefits of using the same or different wells. You have mentioned some of the key issues and Marathon has opted to take the approach of separate wells, recognizing some interpretation of results will be necessary that take different locations into account. The logistics of acquiring the tiltmeter and the microseismic in the same well could complicate and possibly compromise either program. Marathon is working to minimize the variables between the two wells and will look to make improvements on the microseismic projects from the tiltmeter experience.

Reviewer 013B-04 (FUND)

The proposal is well planned, well financed, has a high technical contribution and value. The possibility exists that due to the physics of ND geology the project will not yield useable data. The work has to be performed to answer that question.

Reviewer 013B-09 (Funding May Be Considered)

It can be suggested that a section addressing the shortcomings of the proposed methodology will be included in the proposal. The description should include discussion on proposer's expectations regarding the probability of the successful project completion. Alternative approaches to deal with the challenges should be proposed as well (e.g. in case of sufficient noise on the surface new shallow wells will be drilled by Marathon, etc.).

¹ "Value" – The value of the projected work and technical outcome for the budgeted amount of the project, based on your estimate of what the work might cost in research settings with which you are familiar.

Financial commitment from other sources – A minimum of 50% of the total project must come from other sources to meet the program guidelines. Support less than 50% from Industrial Commission sources should be evaluated as favorable to the application.