LESSONS FROM FAILURES—QUEBEC BRIDGE

Dr Donald E Charrett

Barrister, Melbourne

INTRODUCTION

Collapses of buildings or structures invariably attract considerable public attention, particularly if death or injury results. Government response to significant failures often takes the form of a public inquiry such as a Royal Commission. The terms of reference of such a public inquiry typically includes not only determining the causes of the failure, but also recommendations on avoiding similar failures in the future. The reports of public inquiries are therefore much wider in scope than any report of the litigation between disputing parties involved in a failure, and form a valuable repository of lessons to be learned and guidance for improved practice in the future.

This paper reviews the Royal Commission Report into the first collapse of the Quebec Bridge during its construction. This failure occurred 100 years ago, and in addition to its historical interest, the Report details the lessons learned that are not only timeless, but still relevant today. Although the failure of the Quebec Bridge had a predominantly 'technical' cause in respect of inadequacies in the quality of design and/or construction, the focus of the paper is on the contractual and procedural aspects of project execution (particularly time, cost and scope of work), and the extent to which they may have been contributing factors to the collapse. The deaths resulting from this and other failures are a salutary reminder that failure to implement the appropriate contractual procedures and execute the works in compliance with the requirements of the contract can have much more serious consequences than a dispute over which party is liable to pay damages.

QUEBEC BRIDGE, CANADA (1907)

The Quebec Bridge is known for the two separate failures which occurred during construction, the first in 1907 and the second in 1916, with the tragic death of 86 workers. The day after the first collapse the Canadian government implemented a Royal Commission, empowering it to make immediate investigations into the cause of the collapse of the bridge, and all matters incidental to it. The Commission was chaired by a practising civil engineer, the other two commissioners being another practising civil engineer and the Professor of Engineering at Toronto University. The report itself is a very succinct five pages, but is supported by 19 detailed Appendices and 37 drawings covering all the relevant contractual and technical issues.[1] The Quebec Bridge Royal Commission Report has been studied by generations of engineers for its engineering lessons because of its high standards of honesty, clarity and professional competence, and is 'something of a classic of its kind'.[2]

The Quebec Bridge is a steel bridge of cantilever construction, the main span of 548 m being the longest of this bridge type ever built. It was procured by the Quebec Bridge and Railway Company (QBRC), a company specifically incorporated in 1887 to build and operate a railway bridge across the St Lawrence River. The Government passed various Acts authorising construction of a bridge, subject to approval, as well as the ability to charge tolls (also subject to approval). For a period of 13 years the company was unable to raise the necessary finance, until the Government granted a subsidy of $1 million, subject to completion within a specified time. The province of Quebec and the city of Quebec also made grants totalling $550,000. The company's finances were only assured when in 1903 the Government guaranteed the bonds of the company and enabled it to redeem its outstanding stock.

PROCUREMENT OF THE BRIDGE

The company called lump sum design and construct tenders for main and anchor spans on minimal documentation in September 1898, with a six month tender period. The tender documents included a clearance diagram and specifications for a cantilever bridge with a main span of 488 m (1600'). Four companies submitted tenders for a cantilever bridge and three for a suspension bridge. Mr Theodore Cooper, an eminent American consulting bridge engineer was appointed to report on the tenders, and to act as the company's consulting engineer to review and approve the contractor's designs. Mr Cooper reported that the tenders for a cantilever bridge from the Keystone company and the Phoenix Bridge Company (Phoenix) were acceptable designs, and reported favourably on the tender of Phoenix as the 'best and cheapest'. However he advised that further site investigation was necessary before letting a contract, and there should be provision for changing the specification in any contract that was entered into. Phoenix was not at that stage prepared to enter into a contract because of QBRC's weak financial state.

Once favourable legislation was in prospect, QBRC awarded the contract for the anchor and cantilever spans to Phoenix by a brief agreement in April 1900. Phoenix executed the agreement on the understanding that it was not to become operative until the necessary legislation was enacted and satisfactory financial arrangements for payment had been made, however it did agree to proceed with the design and drawings once formal approval of the government engineers had been obtained. The agreement was extended to include the approach spans in December 1900. The agreement provided, not for a lump sum as tendered, but for the supply and erection of steel at a price per pound, based on the tender price adjusted for changes in the base price of steel. This was apparently the result of Phoenix' tender qualification that its lump sum price was subject to modification for changes in specifications or any other changes 'made by the company's engineer in the size, depths and locations of the piers and their caissons'. Many such changes were made, and arose mainly from the insufficiency of the original plans and the preliminary work done by the QBRC.

After further site investigations and borings, Cooper recommended that the span be increased to 548 m (1800'), which he considered would be quicker to erect and involve fewer risks. He also advised that certain modifications be made to the specifications, to reduce the cost impact of the span increase. These included an increase in allowable stresses in the steel, significantly above those in common use at the time. The Commission considered that this increase in stresses was 'in harmony with the most advanced practice at that time, and due more to an instinct of wise investment than to any endeavour to simply cheapen the structure'.[3] Whilst the government engineers had to give their approval to these changes, it appears they had full confidence in Cooper and did not make any changes to his specification proposals, or interfere with his technical control at any time. Some of that confidence may have been misplaced through a misunderstanding that Cooper would be engaged continuously on the work during construction.[4] As noted below, Cooper did not have any responsibility for the critical erection phase. The Commission however considered that the decision to rely on the advice of Cooper was in accordance with the best knowledge of the time and 'the most competent engineers would have endorsed the concentration of responsibility upon the most experienced and able man'.[5] The revised specifications were not officially approved until the middle of 1903, at which time Phoenix conditionally agreed to the contract.

CRITICISM OF DESIGN & CONSTRUCT PROCUREMENT

The Commission was somewhat critical of the whole process of procurement on a design and construct basis:

... each bridge company was asked to spend several thousand dollars in the preparation of plans, and that in return was given an opportunity to bid for a contract to be let by a company of weak financial standing. The result was that although the magnitude of the work placed it outside the limits of established practice, most of the tenders submitted were made from immature studies based upon insufficient data. The evidence shows that the Phoenix Bridge Company gave more time and attention to the competition than any other tenderer, but the error afterwards made by it in assuming the weight of the structure for final designs shows how faulty the estimate accompanying its original

There were warning signs of significant deformations in major structural members shortly before the collapse, however there was no engineer with the appropriate experience, knowledge and ability in charge of the site in a position to take decisive action. This lack of clarity in the engineering decision–making in QBRC was the subject of criticism by the Commission:

tender was. We consider that the procedure adopted in calling for tenders was not satisfactory in view of the magnitude of the work, and was not calculated to produce the most efficient results.[6]

The Commission criticised the QBRC calling tenders on a general specification which required contractors to prepare plans and designs which were not fully developed, clearly preferring the traditional route of tendering for construction of a fully developed design:

Considering all the conditions pertaining to the undertaking the adoption of this method was not in the best interests of the work. [QBRC] was known not to have the capital necessary to immediately proceed with construction, and the preparation of complete preliminary plans would involve a large outlay. The evidence and documents show that the preliminary plans submitted with the tenders were incomplete; this was as might have been expected, as the several contractors who tendered for the work had little assurance that they would get any return for their expenditure of time and money.

Specifications as a rule consist of two distinct portions, one of which relates to design and the other to fabrication, material and execution. In the case of the Quebec bridge, the difficulty of preparing an adequate specification for design was very great. It would have been better to have entrusted the preparation of plans and specifications to engineers independent of any contracting or manufacturing company, whose previous experience qualified them to handle the work. This course would have avoided duplication of designs involving expensive plans and would have prevented the letting of a contract on incomplete plans formed upon erroneous data; the engineers would have made a proper and sufficient study of the whole project, and in due time competitive tenders upon their plans would have been secured, thus enabling all contractors to tender on a common basis.[7]

THE CONTRACT

The final contract document consisting of 16 Articles of Agreement was executed in June 1903. By today's standards this was a remarkably brief document for such a major project. Phoenix agreed to:

... construct, deliver and erect in the most substantial and workmanlike manner, to the satisfaction and acceptance of [Cooper] and the engineer of [QBRC], and in accordance with the general plans and specifications hereto attached, and made a part of this agreement, the metal superstructure, railings, screens and guard rails, also the timber for tracks and highway floors of the bridge over the St Lawrence River, near Quebec, consisting of one central span of eighteen hundred feet and two side or anchor spans of five hundred feet each.

The contract provided for withholding 10% from progress payments until $100,000 had been withheld, together with a guarantee bond of $100,000 to constitute a fund as a guarantee for the faithful performance of the work under the agreement. As further security for proper performance by Phoenix, all of the plant and equipment was the property of QBRC until completion of the works. There was no requirement for insurance but Phoenix was required to restore at its own cost all or any part of the work damaged or destroyed before its acceptance. Any variation not only required written authorisation by the engineer but approval of the QBRC Board of Directors!

Phoenix provisionally accepted the contract, subject to additional terms it proposed in a separate letter. These provided a condition precedent that the necessary legislation had to be in place, as did satisfactory arrangements for payment. Phoenix stated that it did not guarantee completion by the specified date, nor would it accept responsibility for any delay damages. However, it did agree to pay $5,000 per month in liquidated damages if the work was not complete by 31 December 1908. In February 1904 Phoenix advised that the conditions precedent were satisfied, and no further changes were made to the contractual arrangements. The Commission stated that there was nothing in the various contracts and agreements between QBRC and Phoenix that had a direct connection with the cause of the collapse.[8] Nor was there any inappropriate action by the Government, which maintained all its dealings exclusively with QBRC, which in turn was the only one who dealt with Phoenix.

COST ISSUES

Notwithstanding the financial difficulties of QBRC and the view that design and construct was not the best method of procurement, the Commission did not consider that undue pressure on costs had any bearing on the ultimate failure. Cooper, although he did not overlook costs, made his recommendations for technical reasons, and stated that he was 'left absolutely unhampered in any manner in his report as to which he should consider the best plan and the best bridge'.[9] It is also apparent that letting the contract on a fixed price per pound of steel provided no incentive to the contractor to reduce the steel weight. The specification decisions which were made on design loading and to allow higher stresses than normal were made by Cooper, no doubt with the objective of achieving the best economy he believed was consistent with safe practice. The Commission, and an engineer engaged by QBRC after the collapse to review the design, considered that was an error of judgement, and did not take advantage of the improved financial situation arising from the Government's decision to guarantee QBRC's securities.[10]

Notwithstanding the Commission's view that undue pressure on costs did not have any bearing on the failure, it is difficult to avoid the conclusion that cost–cutting in respect of the engagement of the consulting engineer had an adverse impact on the level of scrutiny that the contractor's design was subject to. The Commission made the following trenchant comments about the consequences of the inadequate remuneration Cooper was paid for his services. Although made 100 years ago, these comments have a timeless quality to them:

Mr Cooper assumed a position of great responsibility, and agreed to accept an inadequate salary for his services. No provision was made by the Quebec Bridge Company for staff to assist him, nor is there any evidence to show that he asked for the appointment of such a staff. He endeavoured to maintain the necessary assistants out of his own salary, which was itself too small for his personal services, and he did a great deal of detail work which could have been satisfactorily done by a junior. The result of this was that he had no time to investigate the soundness of data and theories which were being used in the designing, and consequently allowed fundamental errors to pass by him unchallenged. The detection and correction of these fundamental errors is the distinctive duty of the consulting engineer, and we are compelled to recognize that in undertaking to do his work without sufficient staff or sufficient remuneration both he and his employers are to blame, but it lay with himself to demand that these matters be remedied.[11]

ENGINEERING

At the time of his engagement as consulting engineer to QBRC, Cooper was nearly 70 and in infirm health. Cooper was the engineer who approved all the designs emanating from Phoenix, and the chief engineer of QBRC (Hoare) was responsible for all other technical decisions. Cooper was only concerned with the bridge in its final constructed configuration, and had no involvement with the engineering for erection. He disclaimed any responsibility for inspection in the shop or in the field, and made no site inspections during construction. Although he assumed many of the duties of the chief engineer, he was not authorised to act in this capacity: his directions were advisory and not imperative.

There were warning signs of significant deformations in major structural members shortly before the collapse, however there was no engineer with the appropriate experience, knowledge and ability in charge of the site in a position to take decisive action. This lack of clarity in the engineering decision–making in QBRC was the subject of criticism by the Commission:

The impression left with us is that throughout the work Mr Cooper was in the position of a man forced in the interests of the work to take responsibility which did not fully belong to his position, *and which he was not authorised to take, and that he avoided the assumption of authority whenever possible.*[12]

The reliance on Cooper was in fact a significant factor in the ultimate failure:

His professional standing was so high that his appointment left no further anxiety about the outcome in the minds of all most closely concerned. As the event proved, his connection with the work produced in general a false feeling of security. His approval of any plan was considered by everyone to be final, and he has accepted absolute responsibility for the two great engineering changes that were made during the progress of the work—the lengthening of the main span and the changes in the specification and the adopted unit stresses.[13]

The Government was keen on the bridge opening in 1908, which the Commission considered was one factor which led to Phoenix hurrying the work of design and manufacture and resulting in errors, although not the errors which resulted in the collapse. Phoenix made a significant error in not recalculating the dead weight of the bridge when it commenced the final design in 1903, after the three–year hiatus since its tender was accepted. Both QBRC and Phoenix overlooked this necessity in the rush to complete the final design, with the result that the bridge members would have been considerably overstressed after completion: 'This error was sufficient to have condemned the bridge had it not fallen owing to other causes'.[14] As noted by the Commission, this error could have been detected had the time between 1900 and 1903 been used to prepare the design. The significance of the finding that the bridge would have been overstressed in service had it not collapsed during construction should not be overlooked. As with the much later West Gate Bridge in Melbourne, the tragic collapse during construction averted completion of a bridge which would not have been safe in service.

Cooper did not carry out any independent check on the dead load, and was not aware of the error until February 1906. At this time, the anchor arm, tower and two panels of the cantilever arm were fabricated, and six panels of the anchor arm were in place. He permitted the work to proceed, believing that the increase in stresses from 7 to 10% were still within the limit of safety. The dead loads assumed in design were in fact too low by 18% for the suspended span, 20% for the cantilever arm and 30% for the anchor arm. The use of the preliminary and incorrect values for dead weight in the final design was in breach of the contract, as the specification required that 'The dead weight used for calculating stresses must not be less than the actual weight of structure when completed'.[15] The significance of this error was compounded by the high allowable stresses permitted by Cooper, and the fact that the dead load stresses constituted approximately two thirds of the stress in the main members. The Commission subsequently determined that the error in the design load stresses in the main chords resulting from the incorrect dead load was 10%.[16]

The Commission carried out its own studies and tests on the strength of latticed compression members of the type used in the bottom chords of the anchor arm, and concluded that:

... the bridge fell because the latticing of the lower chords in the main pier was too weak to carry the stresses to which it was subjected; ... We conclude from our tests that owing to the weakness of the latticing, the chords were dangerously weak in the body for the duty they would be called upon to do. We have no evidence to show that they would have actually failed under working conditions had they been axially loaded and not subject to transverse stresses arising from weak end details and loose connections. ... The Phoenix Bridge Company showed indifferent engineering ability in the design of the joints, and did not recognize the great care with which these should be treated in the field.[17]

The Commission looked at the designs of a number of other long span bridges, and compared them with the Quebec Bridge:

Consideration of the difference in the designs on drawings Nos. 34, 35 and 36, all of which have been prepared under the direction of engineers of recognized ability and high professional standing, shows that there is as yet no established system designed for large compression members. The individual judgement of the engineer is the determining factor, and this may prove to be erroneous as it did in the case of the Quebec Bridge.[18]

The design of the latticed compression members did not breach any provisions of the specification, however the design could have been checked by testing:

The main criticism that can be made of the designers was that they had the means of checking their theories by use of the testing machine and that they did not do nor did they thoroughly study the possibilities of lattice formulas.[19]

Pugsley has noted that the engineering significance of this failure was that it drew attention to the lack of knowledge on the behaviour of built–up compression members. Although considerable theoretical work on the design of large compression members was carried out after the Quebec Bridge, testing of major compression members was still prudent in structures such as the Sydney Harbour Bridge.[20]

The materials used satisfied the requirements of the specification, and the standard of Phoenix's detailing, shop work and erection was generally excellent. There were some minor fabrication errors at joints which may have contributed to the collapse, but the real issue for the Commission was a design which called for an accuracy beyond the working limits of good shop practice. The Commission criticised the judgement of some of the Phoenix senior staff, and unequivocally laid the blame for the collapse to the mistakes and errors of its designer, Szlapka. Although widely experienced in bridge design, he had limited knowledge of transportation and erection, and had no responsibility for the engineering for erection. Szlapka had the confidence of Cooper, and, according to the Commission, carried out his design work with care and energy.[21]

ERECTION

Although the Commission considered that the Phoenix erection staff was efficient, well trained and experienced, it did not have an experienced engineer on site responsible for erection:

... the Phoenix Bridge Company erred in judgement and showed a failure to appreciate the magnitude and difficulties of the work it had undertaken when it did not provide as part of this organisation an engineer of erection who, by virtue of technical training and long experience of large bridge work, was fitted to take complete local control of erection. In this they followed usual practice, which, however, was not applicable to this particular work.[22]

The Commission was critical of the inadequate staffing of QBRC, which comprised the chief engineer, two erection inspectors and four mill and shop inspectors, which it did not regard as either efficient or well organised:

The staff was too small; and it is our opinion that the Quebec Bridge Company would have shown better judgement had it employed a larger staff under the direction of an independent man of wide technical knowledge and who would have been sufficiently forceful to hold his own against the contractors.[23]

It did not consider that Hoare was technically competent to fulfil the role of chief engineer and direct the work on site, a fact known to the directors of QBRC:

While we can only consider this as a mistake on the part of the Quebec Bridge and Railway Company, yet we regret to say that such appointments are by no means uncommon, and it must be recognized that in many cases good executive ability is valued more highly or considered of more importance than special professional knowledge.[24]

The lack of a suitably experienced Phoenix erection engineer or QBRC engineer on site became a critical issue during erection of the suspended span when many of the joints were not fully riveted, and major compression members suffered from joint gaps and increasing lateral deflections that gave prior warning of substantial structural distress. The Phoenix erection personnel were unaware of the impending danger, and it was only drawn to Cooper's attention by the QBRC erection inspector when it was too late. The QBRC inspector

The Commission carried out its own studies and tests ... and concluded that:

... the bridge fell because the latticing of the lower chords in the main pier was too weak to carry the stresses to which it was subjected ...

(a qualified but inexperienced engineer) was so concerned with the deformations during erection that he travelled to New York to meet Cooper the day before the collapse. After Cooper was appraised of the situation, he sent a telegram to site warning that all personnel must leave the bridge, however the telegram arrived too late.

THE COMMISSION'S CONCLUSIONS

In the view of the Commission, and an engineer engaged by QBRC after the collapse to review the design, the failure was caused by an error of engineering judgement on the part of both the contractor's design engineer and Cooper. The Commission's concise conclusions are worth repeating in full:

(a) The collapse of the Quebec bridge resulted from the failure of the lower chords in the anchor arm near the main pier. The failure of these chords was due to their defective design.

(b) The stresses that caused the failure were not due to abnormal weather conditions or accident, but were such as might be expected in the regular course of erection.

(c) The design of the chords that failed was made by Mr PL Szlapka, the designing engineer of the Phoenix Bridge Company.

(d) This design was examined and officially approved by Mr Theodore Cooper, consulting engineer of the Quebec Bridge and Railway Company.

(e) The failure cannot be attributed directly to any cause other than errors in judgment on the part of these two engineers.

(f) These errors of judgment cannot be attributed either to lack of common professional knowledge, to neglect of duty, or to a desire to economize. The ability of the two engineers was tried in one of the most difficult professional problems of the day and proved to be insufficient for the task.

(g) We do not consider that the specifications for the work were satisfactory or sufficient, the unit stresses in particular being higher than any established by past practice. The specifications were accepted without protest by all interested.

(h) A grave error was made in assuming the dead load for the calculations at too low a value and not afterwards revising this assumption. This error was of sufficient magnitude to have required the condemnation of the bridge, even if the details of the lower chords had been of sufficient strength, because, if the bridge had been completed as designed, the actual stresses would have been considerably greater than those permitted by the specifications. This erroneous assumption was made by Mr Szlapka and accepted by Mr. Cooper, and tended to hasten the disaster.

(i) We do not believe that the fall of the bridge could have been prevented by any action that might have been taken after August 27, 1907. Any effort to brace or take down the structure would have been impracticable owing to the manifest risk of human life involved.

(j) The loss of life on August 29, 1907, might have been prevented by the exercise of better judgment on the part of those in responsible charge of the work for the Quebec Bridge and Railway Company and for the Phoenix Bridge Company.

(k) The failure on the part of the Quebec Bridge and Railway Company to appoint an experienced bridge engineer to the position of chief engineer was a mistake. This resulted in a loose and inefficient supervision of all parts of the work on the part of the Quebec Bridge and Railway Company.

(l) The work done by the Phoenix Bridge Company in making the detail drawings and in planning and carrying out the erection, and by the Phoenix Iron Company in fabricating the material was good, and the steel used was of good quality. The serious defects were fundamental errors in design.

(m) No one connected with the general designing fully appreciated the magnitude of the work nor the insufficiency of the data upon which they were depending. The special experimental studies and investigations that were required to confirm the judgment of the designers were not made.

(n) The professional knowledge of the present day concerning the action of steel columns under load is not sufficient to enable engineers to economically design such structures as the Quebec bridge. A bridge of the adopted span that will unquestionably be safe can be built, but in the present state of professional knowledge a considerably larger amount of metal would have to be used than might be required if our knowledge were more exact.

(o) The professional record of Mr. Cooper was such that his selection for the authoritative position that he occupied was warranted, and the complete confidence that was placed in his judgment by the officials of the Dominion government, the Quebec Bridge and Railway Company and the Phoenix Bridge Company was deserved'.[25]

The Commission's comment on the 'considerably larger amount of metal' that would have to be used for satisfactory design was confirmed by the redesigned bridge which contained two and a half times the amount of steel as the original design. It is worth noting that although the Commission determined that the direct cause of the collapse was a consequence of engineering errors of judgement, it criticised a number of contractual and procedural aspects as having some significance, specifically (g), (h), (j), (k), (m) and (n) above.

LESSONS FROM QUEBEC BRIDGE

Based on the issues highlighted above, the following are some of the contractual and project execution lessons relevant to major engineering projects to be learned from the Report of the Royal Commission, and which are still relevant today:

- The difficulties and time involved in raising finance for a project should not prevent sufficient time allowance for the preparation of initial studies, the design, tender documentation or for the execution of the works.
- Unquestioning reliance on the skill and experience of an individual engineer may be misplaced without adequate peer review.
- A project owner requires adequately qualified and experienced technical staff with the appropriate authority for both the design and erection phases, even if it procures its project via a design and construct contract.
- The engineering design of a major project should be reviewed by an independent engineer, without reference to the designer's calculations.
- The scope of the engineer's engagement should include responsibility for both design and erection, with compensation commensurate with the proper execution of that scope.
- An owner with limited financial resources may be subject to cost pressures that result in inappropriate engineering decisions.
- The construction contractor needs to have an appropriately qualified and experienced erection engineer on site with an understanding of the design and full authority for the erection.
- Appropriate allowances should be made for the additional risks inherent in unusual structures or structures of a scale not attempted before, and this may require testing of components.

CONCLUSION

Engineering failures inevitably have serious, sometimes grave consequences, but each of them contains lessons to be learned if similar failures and inevitable disputes are to be avoided in the future. The report discussed above contains valuable information, not only historical and technical, but also in respect of contractual and project execution issues that had an influence on the failure of the Quebec Bridge. Although the failure was 100 years ago, the lessons to be learned are timeless. The lessons from this and other past failures are still relevant and worth repeating, as today's generation of building practitioners may not be familiar with the reasons for them, or the resources available in public reports. It is a salutary reminder of the importance of history, that lessons learned and heeded from the contractual issues of scope, time, cost and quality in the execution of projects that failed in the past may assist in preventing failures (and disputes) in the future.

REFERENCES

1. Canada, Royal Commission Quebec Bridge Inquiry, Report (1908)
2. A Pugsley, The Safety of Structures (1963) 140
3. Canada, Royal Commission Quebec Bridge Inquiry, Report (1908) 38
4. Ibid, 42
5. Ibid, 48
6. Ibid, 35
7. Ibid, 141
8. Ibid, 21
9. Ibid, 38
10. Ibid, 150
11. Ibid, 50
12. Ibid, 75
13. Ibid, 49
14. Ibid, 37
15. Ibid, 57
16. Ibid, 109
17. Ibid, 92
18. Ibid, 140
19. Ibid, 150
20. A Pugsley, The Safety of Structures (1963) 141
21. Canada, Royal Commission Quebec Bridge Inquiry, Report (1908) 52
22. Ibid, 53
23. Ibid, 51
24. Ibid, 49
25. Ibid 9–10